AGARD-INDEX 92-94

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AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT
7 RUE ANCELLE, 92200 NEUILLY-SUR-SEINE, FRANCE

AGARD Index of Publications 1992-1994

(Index des publications 1992-1994)

This Index has been prepared as part of the programme of the Technical Information Committee of AGARD.

NORTH ATLANTIC TREATY ORGANIZATION

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North Atlantic Treaty Organization
Organisation du Traité de l'Atlantique Nord

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Contents

Preface

This volume provides abstracts and indexes for AGARD unclassified publications during the period 1992-1994. By an arrangement with U.S. National Aeronautics and Space Administration (NASA) in Washington, DC, the computerized NASA STI Database has been used to prepare this publication.

Full bibliographic citations and abstracts for all the documents in this publication are given in the abstract section, which is organized in the major subject divisions and specific categories used by NASA in abstract journals and bibliographies. The major subject divisions are listed, together with a note for each that defines its scope and provides any cross-references. Category breaks in the abstract section are identified by category number and title, and a scope note. Within each category, the abstracts are arranged by series and year.

Six indexes — Subject (based on *NASA Thesaurus nomenclature*), Personal Author, Corporate Source, Panel, Report/Accession Number, and Accession Number — are included. Sample entries are shown on the first page of each index.

Details of AGARD's classified publications for the same period are contained in a companion, classified, index.

Préface

Ce volume contient des résumés et des indexes relatifs aux publications non-classifiées de l'AGARD parues entre 1992 et 1994. Selon l'accord qui existe entre l'AGARD et l'US National Aeronautics and Space Administration (NASA) à Washington DC, la base de données informatisée STI de la NASA a été utilisée pour la préparation de la présente publication.

Des résumés et des citations détaillées relatifs à tous les documents figurant dans cette publication sont inclus dans la section résumés de l'ouvrage, qui est organisée selon les domaines et les catégories spécifiques employés par la NASA dans ses recueils de résumés et ses bibliographies. Les domaines principaux sont énumérés, avec une note pour chacun d'entre eux, définissant son contenu et indiquant d'éventuels renvois. Les changements de catégories au sein de la section résumés sont identifiés par un numéro de catégorie, un titre et une note de contenu. Les résumés sont classés par série et par année à l'intérieur de chaque catégorie.

Six indexes en tout sont presentés, à savoir, Matière (selon la nomenclature du Thesaurus de la NASA), Auteur individuel, Source collective, Panel, Numéro de rapport/Numéro d'acquisition, et Numéro d'acquisition. Des exemples d'entrées sont donnés à la première page de chaque index.

Le détail des publications classifiées de l'AGARD pour la même période est donné dans un autre index, classifié, dans la même série.

SUBJECT CATEGORIES

AERONAUTICS For related information see also *Astronautics.*

ASTRONAUTICS For related information see also *Aeronautics.*

N.A.—No abstracts were assigned to this category for this issue.

CHEMISTRY AND MATERIALS

ENGINEERING For related information see also *Physics.*

SPACE SCIENCES For related information see also *Geosciences.*

GENERAL

Typical Citation

NASA SPONSORED
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ACCESSION NUMBER → **N94-28035*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA. ← CORPORATE SOURCE

TITLE → **TRANSITIONAL FLIGHT CHARACTERISTICS OF A GEOMETRICALLY SIMPLIFIED STOVL MODEL**

AUTHOR → KARLIN R. ROTH *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) ← **DETAILS OF PARENT:**
- NASA ACCESSION NUMBER (N94-28003)
- ISSUE OF NASA *STAR* (07)
- SUBJECT CATEGORY IN THIS INDEX (34) (i.e., section in which it will be found)

PUBLICATION DATE → Nov. 1993

REPORT NUMBER OF PARENT ITEM, AVAILABILITY SOURCE → (AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

ABSTRACT → The transitional flight characteristics of a geometrically simplified Short Take-Off Vertical Landing (STOVL) aircraft configuration were measured in the NASA Ames 7- by 10-Foot Wind Tunnel. The experiment was designed to provide detailed data for evaluating the capability of computational fluid dynamics methods to predict the important powered lift flow parameters. The model consists of a 60 deg cropped delta wing planform; a blended fuselage; and tandem, circular, high pressure air jets that exit perpendicular to the flat lower surface. Freestream Mach number is limited to a maximum 0.2. Model angle of attack ranges from -10 deg to +20 deg. The nozzle pressure ratios of both jets are varied between 1 and 3, and the jet exit temperatures are maintained at near ambient conditions. Detailed surface pressure measurements show that suction pressure peaks located on the upper surface of the wing during conventional wingborne flight for angles of attack greater than 5 deg move to the wing lower surface at angles of attack less than 0 deg. A reduction in these suction pressure peaks is observed when the lift jets are operating. With sonic jet exit conditions, a freestream Mach number of 0.14, and 0 deg angle of attack, the jet-induced suckdown is equivalent to a 3.7 deg reduction in angle of attack. Schlieren, laser light sheet flow visualization and total pressure measurements in the jet plumes provide a description of the three-dimensional jet efflux flowfield. Author

NB Many AGARD publications, such as Conference Proceedings and Lecture Series, contain a number of individual papers. There is a separate citation in this index for each such paper, each containing a cross-reference (34 in this instance) to the parent publication in the form shown above. To locate the parent in this index, refer to the subject category given in the cross-reference. Within each category, citations are in numerical order.

AGARD INDEX OF PUBLICATIONS (1992–1994)

ABSTRACT SECTION

01

AERONAUTICS (GENERAL)

N92-27887# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
AIR VEHICLE MISSION CONTROL AND MANAGEMENT
Mar. 1992 260 p In ENGLISH and FRENCH The 53d symposium was held in Amsterdam, Netherlands, 22-25 Oct. 1991
(AGARD-CP-504; ISBN-92-835-0662-6; AD-A253088) Copyright Avail: CASI HC A12/MF A03

Presented here are 21 unclassified papers presented at the Guidance and Control Panel Symposium held at the Marine Kazerne, Amsterdam, The Netherlands from October 22 to 25, 1991. Topics covered include operational mission considerations, situation assessment, route planning, mission planning, expert systems, aircraft guidance and control, fuzzy logic, flight control, and trajectories. For individual titles, see N92-27888 through N92-27907.

N92-28522# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
PILOTED SIMULATION EFFECTIVENESS [L'EFFICACITE DE LA SIMULATION PILOTEE]
Feb. 1992 349 p In ENGLISH and FRENCH Symposium held in Brussels, Belgium, 14-17 Oct. 1991
(AGARD-CP-513; ISBN-92-835-0656-1; AD-A253007) Copyright Avail: CASI HC A15/MF A03

The ability of piloted simulators to represent military and civil aviation operational tasks with ever increasing levels of fidelity is leading to a steady growth in their use for all areas of aviation from new concept studies, through support for development and flight clearance, to training aircrews for complex missions. The papers here present a variety of experience of the effectiveness of simulation for many of the key areas of application. This session focuses on: the use of simulation in aircraft development programs; the use of simulation in developing piloting skills; the use and potential of simulation in full mission training for military roles; and the effectiveness of simulation for a variety of research tasks. For individual titles, see N92-28523 through N92-28552.

N94-18415# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
HIGH-LIFT SYSTEM AERODYNAMICS [L'AERODYNAMIQUE DES SYSTEMES HYPERSUSTENTATEURS]
Sep. 1993 494 p The 71st Symposium held in Banff, Alberta, 5-8 Oct. 1992
(AGARD-CP-515; ISBN-92-835-0715-0) Copyright Avail: CASI HC A21/MF A04

This report includes the 32 technical papers developed for the High-Lift System Aerodynamics Symposium along with an edited transcript of the Round Table Discussion and a Symposium Evaluation Report. The symposium objectives were to address (1) how the most appropriate high-lift system can be selected; (2) how an efficient design can be produced; and (3) the experimental and analysis techniques which are necessary to explore and enhance the performance of a high-lift system. Thus, although the aerodynamics of high-lift systems was the dominant theme, the very pertinent aspects of weight, simplicity, reliability, and structural and mechanical integrity were an integral part of the Symposium, and were treated in the papers presented. In this sense, this Symposium has attempted to take a broader view of the high-lift system than has been taken by similar conferences in the past. For individual titles, see N94-18416 through N94-18447.

N94-18416# Defence Research Agency, Farnborough, Hampshire (England). Low Speed Aerodynamics Div.
WHERE IS HIGH-LIFT TODAY? A REVIEW OF PAST UK RESEARCH PROGRAMMES
D. S. WOODWARD and D. E. LEAN *In* AGARD, High-Lift System Aerodynamics 45 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

Some of the history of the development of slotted high-lift systems is reviewed in this paper. In particular, the National High Lift Programme run in the UK during the 1970's is reviewed in some detail. In addition, the research program in high lift since the completion of the National High Lift Programme is described qualitatively and references given. The contents cover techniques of high lift testing, results of positional optimization of slats and flaps, the derivation of a simple prediction method suitable for use with a project optimization method, and the description, with results, of a method for interpreting aerodynamic and weight data on high lift systems in the context of a complete aircraft.
Author (revised)

N94-18441# Fokker B.V., Schipol-Oost (Netherlands).
FORTY YEARS OF HIGH-LIFT R/D: AN AIRCRAFT MANUFACTURER'S EXPERIENCE
E. OBERT *In* AGARD, High-Lift System Aerodynamics 28 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

In the course of four decades a large amount of high-lift applied research and development has taken place at the Fokker Company. In the fifties and sixties the F-27 and the F-28 were developed. In the eighties these aircraft were developed further into the Fokker 50 and Fokker 100. In the seventies an extensive R&D program was performed in preparation of a possible successor to the F-28 leading to the F-29 project study. In each case two- and three-dimensional wind tunnel models were investigated in numerous configurations. In the last decade these investigations have increasingly been preceded by theoretical investigations. Where data are available comparisons have been made with flight test data. Of each development program a detailed account is presented. Particular attention is paid to Reynolds-number effects and the interconnection between the high-speed cruise and low-speed high-lift design requirements. Author

NOTICE
The single asterisk following the accession number indicates that the report is NASA sponsored.

02

AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

N92-23956*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HIGH ANGLE OF ATTACK: AERODYNAMICS
JOHN E. LAMAR *In* AGARD, Special Course on Engineering Methods in Aerodynamic Analysis and Design of Aircraft 39 p (SEE N92-23950 14-05) Jan. 1992
(AGARD-R-783) Copyright Avail: CASI HC A03/MF A03
The ability to predict high angle of attack, nonlinear, aerodynamic characteristics of flight vehicles, including aircraft, has made significant progress in the last 25 years using computational tools and analyses. The key technological element which has made these analyses possible is the ability to account for the influence of the shed vortical flow, prevalent in this angle of attack range, on geometries of interest. Using selected analysis techniques, applications have also been made to wing design in order to improve their high speed maneuver performance. Various techniques, associated with different levels of accuracy, exist to model this vortical flow influence. The ones included in this paper cover: suction analogy with extensions; free vortex filaments; free vortex sheet modeling; and Euler and Navier-Stokes solutions. Associated relevant features of vortices are also addressed, including: the wing and flow conditions which cause vortex formation; and how the vortex strength varies with angle of attack and wing sweep. Author

N92-27706# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON SKIN FRICTION DRAG REDUCTION
Mar. 1992 284 p Course held in Rhode-Saint-Genese, Belgium, 2-6 Mar. 1992; sponsored in cooperation with VKI
(AGARD-R-786; ISBN-92-835-0661-8; AD-A253005) Copyright Avail: CASI HC A13/MF A03
Lecture notes for the AGARD Fluid Dynamics Panel (FDP) Special Course on 'Skin Friction Drag Reduction' have been assembled in this report. The aim and scope of this course was to provide an overview of the state of the art of current technology programs focused on reducing aircraft drag caused by skin friction. This report provides a review of recent progress in the field of skin friction drag reduction for transport aircraft. It provides a general introduction to the technology and then focuses on two specific aspects of drag reduction: maintaining laminar flow by controlling transition and manipulating the turbulence structure in boundary layers to help reduce skin friction. Technology associated with the use of riblets, LEBU, polymers, additives, etc., is also reviewed. For individual titles, see N92-27707 through N92-27714.

N92-27707# Centre d'Etudes et de Recherches, Toulouse (France).
BASIC CONCEPTS ON BOUNDARY LAYERS
JEAN COUSTEIX *In* AGARD, Special Course on Skin Friction Drag Reduction 39 p (SEE N92-27706 18-02) Mar. 1992
(AGARD-R-786) Copyright Avail: CASI HC A03/MF A03
At the present time drag reduction is an industrial challenge in aeronautics which justifies the efforts devoted to this topic. One facet of this effort deals with the skin friction drag reduction. Two directions are followed. The first one is the manipulation of turbulent boundary layers, by altering the formation of turbulence or by modifying its characteristics it is hoped to decrease the turbulent skin friction. The second direction concerns the action on laminar-turbulent transition, by delaying the occurrence of the turbulent regime, enormous skin friction reductions are possible. It is believed that the improvements in the field are based on a better knowledge of the basic phenomena. Author

N92-27708# Airbus Industrie, Blagnac (France).
DRAG REDUCTION: AN INDUSTRIAL CHALLENGE
J. P. ROBERT *In* AGARD, Special Course on Skin Friction Drag Reduction 15 p (SEE N92-27706 18-02) Mar. 1992
(AGARD-R-786) Copyright Avail: CASI HC A03/MF A03
Over the last few decades all civil aircraft manufacturers have made great efforts to reduce aircraft drag. The long term aim of the operation is to reduce the specific fuel consumption of aircraft, the potential reduction of over 10 percent would represent savings of several million dollars for the airlines. The fuel crises have increased the need for developing new technologies to be applied on the new aircraft; retrofits, however, also have their uses. Estimating the drag of a transport aircraft through calculation or wind tunnel tests must come as close as possible to the value obtained in flight. H.A.

N92-27709* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AIRCRAFT DRAG REDUCTION
D. M. BUSHNELL *In* AGARD, Special Course on Skin Friction Drag Reduction 16 p (SEE N92-27706 18-02) Mar. 1992
(AGARD-R-786) Copyright Avail: CASI HC A03/MF A03
This paper reviews aerodynamic drag reduction for friction, wave and vortex drag associated with supersonic cruise aircraft and suggests approaches and research directions which cover the spectrum from possibly significant to revolutionary. Various synergisms are also included, especially in regard to suction laminar flow control and flow separation control at cruise. The former may also enable improved low speed, high lift systems, lift to drag ratio for subsonic cruise, reduced parasitic viscous drag for favorable interference wave drag reduction approaches, and turbulent skin friction reduction via slot injection. Flow separation control at cruise proffers opportunities for increased leading edge thrust, increased lift increment from upper surface, increased fuselage lift/camber for wave drag due to lift reduction, improved performance of various favorable interference wave drag reduction schemes, as well as possibly better low speed, high-schemes and wing cruise performance. More speculative approaches include multi-stage aircraft, thrust vectoring for lift augmentation, as well as trim, and a number of conceptual wave and vortex drag reduction schemes. Author

N92-27710# Arizona State Univ., Tempe, AZ. Dept. of Mechanical and Aerospace Engineering.
LAMINAR-TURBULENT TRANSITION: FUNDAMENTALS
WILLIAM S. SARIC *In* AGARD, Special Course on Skin Friction Drag Reduction 32 p (SEE N92-27706 18-02) Mar. 1992
(AGARD-R-786) Copyright Avail: CASI HC A03/MF A03
The basic instability mechanisms are discussed from an elementary standpoint considering only boundary layers in external flows. The objective of this report is to provide the basic ideas and results of boundary layer stability in order that one can understand transition mechanics, transition control, and transition prediction for aircraft systems. The current state of the art boundary layer stability is reviewed and by using recent results, it is shown that a number of unique transition mechanisms exist and each play a different role in the breakdown to turbulence. The control of the stability and transition characteristics of a particular flow field requires thoroughly understanding the details of these breakdown mechanisms. Author

N92-27711# Centre d'Etudes et de Recherches, Toulouse (France). Dept. of Aerothermodynamics.
BOUNDARY LAYER TRANSITION: PREDICTION, APPLICATION TO DRAG REDUCTION
D. ARNAL *In* AGARD, Special Course on Skin Friction Drag Reduction 59 p (SEE N92-27706 18-02) Mar. 1992
(AGARD-R-786) Copyright Avail: CASI HC A04/MF A03
This paper describes the practical calculation methods which are currently available to predict the transition location in two and three dimensional flows. Emphasis is given to the problem of skin friction drag reduction on swept wings at subsonic and transonic speeds. The so called e(sup n) method, which is deduced from the linear stability theory is widely used in the case of 'natural' transition, but simpler techniques (empirical criteria) are useful in more complex situations such as boundary layer tripping or leading edge contamination. The simulation of flight in wind tunnels is also discussed. Wind tunnel/flight correlation includes comparisons

between the free stream disturbance environment, the transition Reynolds number, and the n factor at transition onset. Author

N92-27712# University of Southern California, Los Angeles, CA. Dept. of Aerospace Engineering.
THE EDDY STRUCTURES IN BOUNDED SHEAR FLOWS
RON F. BLACKWELDER *In* AGARD, Special Course on Skin Friction Drag Reduction 18 p (SEE N92-27706 18-02) Mar. 1992
(Contract(s)/Grant(s): N00014-82-K-0084; N00014-86-K-0679; F49620-85-C-0080)
(AGARD-R-786) Copyright Avail: CASI HC A03/MF A03

The near wall turbulent eddies consist of streamwise vortices, low speed streaks, intense shear layers, inflectional velocity profiles, oscillations and ejections of low speed fluid out into the logarithmic layer. Away from the wall, large scale three dimensional outer structures dominate the flow. A mass of data has been accumulated over the past 25 years concerning these eddies and their interaction. These eddies and events will be discussed as well as their Reynolds number dependence. Author

N92-27713*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
STUDY OF TURBULENCE STRUCTURE THROUGH NUMERICAL SIMULATIONS: THE PERSPECTIVE OF DRAG AND REDUCTION
J. J. KIM *In* AGARD, Special Course on Skin Friction Drag Reduction 14 p (SEE N92-27706 18-02) Mar. 1992
(AGARD-R-786) Copyright Avail: CASI HC A03/MF A03

The first part of this note concerns organized structures in the near-wall region of a turbulent boundary layer. A particular emphasis is given to those organized motions believed to be responsible for the turbulence production process in the wall region, and hence, indirectly responsible for the viscous drag. Examples are selected to illustrate how the analyses of numerically generated databases have contributed to improve our understanding of the organized structures of turbulent boundary layers. In the second part, results from an exploratory study based on the direct numerical simulation of the concepts for active control of turbulent boundary layers are presented. A significant drag reduction is achieved when the surface boundary condition is modified such that it could suppress the organized motion in the wall region. This drag reduction is accompanied by a significant reduction in the intensity of the organized structures and in the magnitude of Reynolds stresses throughout the flow. Author

N92-27714# Centre d'Etudes et de Recherches, Toulouse (France). Aerothermodynamics Dept.
TURBULENT SKIN-FRICTION DRAG REDUCTION BY ACTIVE AND PASSIVE MEANS, PART 1
E. COUSTOLS (Office National d'Etudes et de Recherches Aeronautiques, Paris (France).) and A. M. SAVILL (Cambridge Univ., England) *In* AGARD, Special Course on Skin Friction Drag Reduction 80 p (SEE N92-27706 18-02) Mar. 1992 Sponsored in part by Rolls-Royce Ltd.; Cambridge Univ.; Airbus Industrie; Aerospatiale; British Aerospace Aircraft Group; BACC; and BMT
(Contract(s)/Grant(s): SERC-GR/E/06824; SERC-GR/E/77039)
(AGARD-R-786) Copyright Avail: CASI HC A05/MF A03

The purpose of this paper is to provide a current overview of turbulent skin friction drag reduction concepts which have potential for reducing aircraft fuel consumption. These lectures are organized around four topics. First, after briefly reviewing what is known about the structure of the turbulent boundary layer, possible mechanisms for both active and passive will be discussed; concentrating on techniques offering net drag benefits, either through inner or outer layer manipulation. Both experimental and numerical results will be presented for these boundary layer manipulators. Available data and computer model predictions for low and high subsonic speeds, transonic conditions, and supersonic flow will be reviewed. The aim will be to outline the most important results obtained in terms of drag reduction, and to emphasize the most recent developments. Finally, the combination of passive devices with polymers, suction, blowing, microbubbles, or acoustic forcing will be discussed along with studies of alternative drag reducing surfaces. Author

N92-27936# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
TRANSONIC UNSTEADY AERODYNAMICS AND AEROELASTICITY
Mar. 1992 396 p In ENGLISH and FRENCH The 73d meeting was held in San Diego, CA, 7-11 Oct. 1991 Original contains color illustrations
(AGARD-CP-507; ISBN-92-835-0660-X; AD-A253603) Copyright Avail: CASI HC A17/MF A04

Given here are papers presented at a Specialists' Meeting organized by the Structures and Materials Panel of AGARD and held at its Fall 1991 Meeting. Topics covered include transonic unsteady aerodynamics, aeroelasticity, various methods of calculation, and engineering-level aeroelastic prediction techniques. For individual titles, see N92-27937 through N92-27962.

N92-27937*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CURRENT STATUS OF COMPUTATIONAL METHODS FOR TRANSONIC UNSTEADY AERODYNAMICS AND AEROELASTIC APPLICATIONS
JOHN W. EDWARDS and JOHN B. MALONE *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 24 p (SEE N92-27936 18-02) Mar. 1992 Previously announced as N92-21432
(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

The status of computational methods for unsteady aerodynamics and aeroelasticity is reviewed. The key features of challenging aeroelastic applications is discussed in terms of the flowfield state - low angle high speed flows and high angle vortex dominated flows. The critical role played by viscous effects in determining aeroelastic stability for conditions of incipient flow separation is stressed. The need for a variety of flow modeling tools, from linear formulations to implementations of the Navier-Stokes equations, is emphasized. Estimates of computer run times for flutter calculations using several computational methods are given. Applications of these methods for unsteady aerodynamic and transonic flutter calculations for airfoils, wings, and configurations are summarized. Finally, recommendations are made concerning future research directions. Author

N92-27938*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
UNSTRUCTURED-GRID METHODS DEVELOPMENT FOR UNSTEADY AERODYNAMIC AND AEROELASTIC ANALYSES
JOHN T. BATINA, ELIZABETH M. LEE, WILLIAM L. KLEB, and RUSS D. RAUSCH (Purdue Univ., West Lafayette, IN.) *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 10 p (SEE N92-27936 18-02) Mar. 1992 Previously announced as N91-32084
(AGARD-CP-507) Copyright Avail: CASI HC A02/MF A04

The current status of unstructured grid methods developed in the Unsteady Aerodynamics Branch at NASA Langley Research Center is described. These methods are being developed for unsteady aerodynamic and aeroelastic analyses. Flow solvers that have been developed for the solution of unsteady Euler equations are highlighted. The results demonstrate two and three dimensional applications for both steady and unsteady flows. Comparisons are also made with solutions obtained using a structured grid code and with experimental data to determine the accuracy of the unstructured grid methodology. These comparisons show good agreement which thus verifies the accuracy. Author

N92-27939# Wright Lab., Wright-Patterson AFB, OH. Aeroelasticity Group.
UNSTEADY AERODYNAMICS FOR AEROELASTICITY AT THE FLIGHT DYNAMICS DIRECTORATE
M. BLAIR, L. J. HUTTSELL, W. A. SOTOMAYER, and T. M. HARRIS *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 10 p (SEE N92-27936 18-02) Mar. 1992
(AGARD-CP-507) Copyright Avail: CASI HC A02/MF A04

An overview is presented of the recent in-house and contractual efforts in the area of transonic unsteady aerodynamics for aeroelasticity at the Flight Dynamics Directorate of the USAF Wright Laboratory. Three major topics are discussed. The first topic, analytical unsteady aerodynamics, involves the application of both transonic small disturbance and Euler/Navier-Stokes codes to

fighter-type aircraft. Aeroelastic calculations made with these codes are compared with test results. The second topic involves a description of unsteady pressure testing in the NLR tunnel in the Netherlands. Finally, the plan for incorporating transonic unsteady aerodynamics into structural redesign is presented. Author

N92-27940# Saab Aircraft Co., Linkoeping (Sweden). Dept. of Aeroelasticity.

RECENT APPLICATIONS OF LINEAR AND NONLINEAR UNSTEADY AERODYNAMICS FOR AEROELASTIC ANALYSIS

BENGT WINZELL *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 10 p (SEE N92-27936 18-02) Mar. 1992 Sponsored in part by Swedish Defence Administration

(AGARD-CP-507) Copyright Avail: CASI HC A02/MF A04

Results of unsteady linear and full potential theory are used for analysis of wings and aircraft configurations. In particular, the details of unsteady pressure distributions at the trailing edge are investigated, aiming at better representation of control surface hinge moments. The importance of viscous effects are observed and a comparison between potential theory and Navier-Stokes predictions is made. Author

N92-27941# Alberta Univ., Edmonton (Alberta). Dept. of Mathematics.

A TIME-LINEARIZATION APPROACH FOR UNSTEADY TRANSONIC FLOWS

Y. S. WONG (Alberta Univ., Edmonton.), B. H. K. LEE (National Research Council of Canada, Ottawa (Ontario).), and H. S. MURTY (Ottawa Univ., Ontario) *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 22 p (SEE N92-27936 18-02) Mar. 1992 Sponsored by Dept. of National Defence and Natural Sciences and Engineering Research Council

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

The development of a time-linearization approach for solving the unsteady transonic small disturbance equation is described in UST3D simulation code (UnSteady Transonic code for a 3D isolated wing). The accuracy of the method was examined by comparing the unsteady pressure distributions with those obtained from XTRAN3S code and experiments carried out on the F-5 wing at subsonic and transonic wings to show the deficiencies of the method. Using the UST3D code, flutter analysis was carried out on the AGARD 445.6 wing. The flutter boundaries were compared with experimental results and those from CAP-TSD code. Author

N92-27942# Rome Univ. (Italy).

A BOUNDARY INTEGRAL FORMULATION FOR UNSTEADY TRANSONIC POTENTIAL FLOWS

U. IEMMA (Rome Univ. (Italy).), F. MASTRODDI (Rome Univ. (Italy).), L. MORINO (Rome Univ. (Italy).), and M. PECORA (Alenia Spazio S.p.A., Rome, Italy) *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 11 p (SEE N92-27936 18-02) Mar. 1992 Sponsored by Italian Aerospace Research Center

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

A boundary integral formulation for the analysis of unsteady potential transonic flows around airplanes is presented. The formulation is applied to steady and to unsteady two dimensional and three dimensional configurations under the small perturbation assumption. The results are compared with existing numerical and/or experimental results, and demonstrate that the algorithm is capable of capturing shocks. However, the location predicted appears to be ahead of that predicted by conservative finite difference schemes; nevertheless, considering the preliminary nature of this work, the agreement obtained is quite satisfactory. Author

N92-27943# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany). Inst. of Aeroelasticity.

COMPARISON OF EULER AND FULL POTENTIAL METHODS FOR UNSTEADY TRANSONIC FLOW CALCULATIONS

R. VOSS and W. WEGNER *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 17 p (SEE N92-27936 18-02) Mar. 1992

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Presented here are the results of unsteady transonic flow calculation methods developed at the DLR Institute of Aeroelasticity for oscillating airfoils and wings. The 2D Euler and Full Potential calculations in the nonlinear regime with pronounced shock dynamics at the conventional NACA0012 and the supercritical NLR7301 airfoil show that the unsteady pressure distributions agree well, whereas the unsteady lift and moment curves are not always in good agreement. The 3D results are obtained with a 3D Full potential code and a 3D time linearized TSD method for a swept NACA0012 wing and for a LANN wing, an AGARD standard test wing, both oscillating with small amplitudes. The agreement of the first harmonics of pressure distribution indicates that the time linearized approach may be sufficient for low amplitudes. For higher amplitudes, however, the appearance of pronounced higher harmonics indicates strong nonlinear behavior combined with complicated shock motions. Author

N92-27944# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany). Inst. of Aeroelasticity.

COMPUTATION OF THE UNSTEADY TRANSONIC 2D CASCADE FLOW BY AN EULER ALGORITHM WITH INTERACTIVE GRID GENERATION

V. CARSTENS *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 14 p (SEE N92-27936 18-02) Mar. 1992

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

Numerical results of a code for computing the unsteady transonic flow in a 2D cascade of harmonically oscillating blades are given. The calculation of the flow field is based on a Euler code using flux vector splitting. After a description of the basic equations and the special numerical techniques applied to the code, results are presented for the first harmonics of pressure, lift, and moment coefficients. For the present investigations, two basic oscillation modes were chosen: tuned modes where all blades perform oscillations with the same frequency, same amplitude and a constant interblade phase angle, and mistuned modes, where all blades are oscillating with the same amplitude, but with varying frequency from one blade to another. The computed results refer to two standard configurations: a subsonic-transonic turbine cascade and a subsonic-transonic compressor cascade. In the case of tuned bending modes, the theoretical results are compared with the experimental data from the turbine standard configuration. Special attention is directed to the occurrence of aerodynamic instability in the oscillating cascade. It can be shown that the interblade phase angles at which the above mentioned experimental test case shows unstable behavior are generally well-reproduced by the computational results. Author

N92-27945# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.

EVALUATION OF AN UNSTEADY IMPLICIT EULER CODE AGAINST TWO AND THREE-DIMENSIONAL STANDARD CONFIGURATIONS

A. BRENNEIS and A. EBERLE *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 15 p (SEE N92-27936 18-02) Mar. 1992

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

The numerical simulation of the unsteady Euler equations in conservative form for time-accurate problems using a relaxation method is considered. The unfactored implicit equations are solved by applying a nonlinear Newton method. Relaxation is performed with a point Gauss-Seidel algorithm ensuring a high degree of vectorization by employing the so-called checkerboard scheme. The fundamental feature of the Euler solver is a characteristic variable splitting scheme (Godunov-type averaging procedure, linear locally one-dimensional Riemann solver) based on an Eigenvalue analysis for the calculation of fluxes. Singular behavior of the coefficient matrix is evaded by a simple matrix conditioning needing only a few operations. Numerical results are presented for two and three dimensional standard AGARD configurations. The airfoils and wings at sub and transonic flows perform harmonically pitching oscillations or trailing edge flap oscillations. Comparisons with experiments show good agreement except in regions where viscous effects are evident. Author

N92-27946# Escuela Tecnica Superior de Ingenieros Aeronauticos, Madrid (Spain).
UNSTEADY TRANSONIC AERODYNAMICS OF POINTED BODIES OF REVOLUTION IN SUPERSONIC FREESTREAM
P. GARCIAFOGEDA and A. SANZ *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 9 p (SEE N92-27936 18-02) Mar. 1992 Sponsored by Polytechnical Univ. of Madrid
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A method was developed to determine the aerodynamic forces acting on oscillating bodies of revolution in transonic-supersonic flight. The nonlinear equation for the mean flow perturbation potential and the time linearized equation for the cross flow perturbation are both of hyperbolic type, for the Mach number range of interest, and have been solved by the method of characteristics. The method is valid for arbitrary frequencies of oscillation and can be applied for rigid or flexible body motions. Results are presented for the stability force coefficients, unsteady pressure distributions, and shock deformations for various body shapes and Mach numbers. Author

N92-27947# National Aerospace Lab., Amsterdam (Netherlands).
NLR INVISCID TRANSONIC UNSTEADY LOADS PREDICTION METHODS IN AEROELASTICITY
M. H. L. HOUNJET *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 16 p (SEE N92-27936 18-02) Mar. 1992 Sponsored in part by Royal Dutch Airforce
(Contract(s)/Grant(s): NIVR-01904-N)
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An overview is presented of unsteady inviscid calculation methods at the National Aerospace Laboratory (NLR), which are primarily based on the full potential equation for the prediction of airloads on oscillating structures in transonic flow. Attention is given to experience with entropy/vorticity corrections and a procedure which removes the frequency barrier associated with time-linearized modelings. This procedure has a favorable effect on computer cost such that transonic flutter boundaries can be obtained in acceptable turn-around times on current workstations. A method for transonic aeroelastic analysis of complete aircraft which is now in the stage of development is introduced, and attention is given to its grid generation procedure. The methods are demonstrated by showing results of unsteady loads and pressure coefficients applications in 2D and 3D transonic flow and an aeroelastic application to a 3D AGARD standard aeroelastic case in transonic flow. Author

N92-27948# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany). Numerical Fluid Mechanics Div.
COMPUTATIONS OF UNSTEADY FLOWS AROUND AIRFOIL SECTIONS BY EXPLICIT AND IMPLICIT METHODS SOLVING THE EULER AND NAVIER-STOKES EQUATIONS
EDGAR A. GERTEISEN *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 13 p (SEE N92-27936 18-02) Mar. 1992
(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

A Euler/Navier Stokes solution algorithm is presented for unsteady aerodynamic analysis of flows around airfoil sections. Several numerical methods have been involved in the flow solver, beginning with an explicit Runge-Kutta time-stepping scheme. Two methodological closely connected moving mesh algorithms were implemented, concerning the mesh adaption for improved accuracy with a minimal number of mesh points, and the body conforming mesh movement which is completely general and can treat realistic configurations. A description is given of the latest version of the developed implicit solving algorithm which can be used as a direct method, but also includes an option for iterating the unsteady residual to enhance the time accuracy. The included moving mesh methods for solution adapting and body conforming the grid are summarized. Numerical simulations of steady and unsteady well known flow phenomena, comprising a shock/boundary interaction, a flow around a cylinder, an airfoil with oscillating flap, and a circular arc airfoil substantiate the above mentioned topics. Author

N92-27949# Deutsche Airbus G.m.b.H., Bremen (Germany). Dept. Aeroelastics.
COMPUTATION OF VISCOUS PHENOMENA IN UNSTEADY TRANSONIC FLOW
U. R. MUELLER, H. HENKE, and K. DAU *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 16 p (SEE N92-27936 18-02) Mar. 1992
(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

Progress towards the development of a 3D viscous-inviscid strong interaction method for computing unsteady transonic wing flow is reported. In the current version, an ADI technique for solving the 3D unsteady Transonic Small Perturbation (TSP) equation has been extended by incorporating an unsteady 2D integral boundary layer method and then simultaneously solving the viscous and inviscid flow equations in a stripwise fashion. Here attention is focused on the viscous part of the method, and a 3D boundary layer version is introduced. Detailed calculations of 2D unsteady and 3D incompressible/compressible turbulent boundary layers were performed by the integral methods and also by a finite difference solver, and the results are compared to experimental data. The strong interaction technique is validated by comparison with experimental pressure distributions on several airfoils and a wing for various transonic Mach numbers. For steady and unsteady flows, the computed influence of viscous displacement on the pressure distribution is demonstrated in contrast to purely inviscid calculations. Author

N92-27950# British Aerospace Aircraft Group, Kingston-upon-Thames (England). Military Aircraft Div.
TRANSONIC AEROELASTIC CALCULATIONS IN BOTH THE TIME AND FREQUENCY DOMAINS
M. J. KNOTT *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 8 p (SEE N92-27936 18-02) Mar. 1992
(AGARD-CP-507) Copyright Avail: CASI HC A02/MF A04

A method for exploring the flutter characteristics of wing-only configurations in the transonic flow regime is presented. At the heart of the method is the Unsteady Transonic Small Perturbation (UTSP) program, which solves the nonlinear transonic small perturbation equation with or without the simultaneous integration of the structural equations of motion. The aim here is to describe the functionality of the program, with a particular emphasis on its implementation within the existing aeroelastics analysis environment at the Kingston site of British Aerospace. Before demonstrating the use of the UTSP program on a production conbat wing, results for the AGARD Taileron and wing 445.6 models are presented, with the aim of validating the method. Author

N92-27951# McDonnell Aircraft Co., Saint Louis, MO.
AEROELASTIC CALCULATIONS FOR FIGHTER AIRCRAFT USING THE TRANSONIC SMALL DISTURBANCE EQUATION
DALE M. PITT and DENNIS F. FUGLSANG *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 11 p (SEE N92-27936 18-02) Mar. 1992
(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

The Transonic Small Disturbance (TSD) equation provides a fast and efficient tool for calculating both static and dynamic nonlinear aerodynamic effects. To become an accepted part of the aircraft design process, time-accurate TSD equation solvers for aeroelastic calculations now need to be evaluated on realistic aircraft configurations that have complex geometry. Discussed here is the application of NASA Langley's Computational Aeroelastic Program - Transonic Small Disturbance (CAP-TSD) code for both static and dynamic transonic aeroelastic calculations for McDonnell Aircraft Company's F-15 and F/A-18 fighter aircraft. The results for flutter speed and aileron reversal speed are compared with results from standard linear aerodynamic analysis. Author

N92-27952# Deutsche Airbus G.m.b.H., Bremen (Germany). Dept. Aeroelastics.
COMPUTATION OF FLUTTER BOUNDARIES IN THE TIME AND FREQUENCY DOMAIN
H. ZIMMERMANN, S. VOGEL, H. HENKE, and B. SCHULZE *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 9 p (SEE N92-27936 18-02) Mar. 1992
(AGARD-CP-507) Copyright Avail: CASI HC A02/MF A04

Computations of flutter boundaries in the time and frequency domain are presented using an interactive 3D Transonic Small Perturbation code. Results of conventional flutter calculations in

the frequency domain are opposed to those of flutter simulations integrating the aerodynamic and structural equations of motion simultaneously in the time domain. Highlighted here are the basic properties of these two approaches and the results for a six and a two degrees of freedom model. A comparison of generalized airloads determined by harmonic and pulse excitation is presented. Author

N92-27953# Boeing Co., Seattle, WA.

ANALYSIS OF UNSTEADY AERODYNAMIC AND FLUTTER CHARACTERISTICS OF AN AEROELASTIC MODEL IN TRANSONIC FLOW

G. SENGUPTA, C. J. BORLAND, F. T. JOHNSON, J. E. BUSSOLETTI, R. G. MELVIN, D. P. YOUNG, M. B. BIETERMAN, and P. A. PALOTAS *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 18 p (SEE N92-27936 18-02) Mar. 1992 Original contains color illustrations

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

Prediction of unsteady pressure distributions is an important step towards analyzing the flutter characteristics of an airplane. For this purpose, the TRANSAIR code, originally developed for predicting steady transonic flow past bodies of complex geometry, was extended to handle unsteady problems, in which the unsteady solution could be viewed as an harmonic perturbation to the steady transonic flow. The predicted unsteady flow effects were compared with linear solutions for subsonic flow problems. The predicted results were also compared with available experimental data on unsteady pressure distributions on an oscillating wing in transonic flow. In all these cases, excellent agreements were obtained. The unsteady TRANSAIR code and a structural finite element code were then used to analyze the flutter characteristics of a three dimensional wing model. The predicted flutter speeds and frequencies, including nonlinear flow effects were significantly different than those predicted by linear analysis. Further analyses including the effects of nacelles and fuselage bodies are in progress. Author

N92-27954# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

DIRECT COUPLING OF FLUID STRUCTURE IN TRANSONIC AEROELASTICITY [COUPLAGE DIRECT FLUIDE STRUCTURE EN AEROELASTICITE TRANSSONIQUE]

J. P. GRISVAL and J. L. MEURZEC *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 14 p (SEE N92-27936 18-02) Mar. 1992 In FRENCH; ENGLISH summary Previously announced in IAA as A91-16744

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Presented here is a numerical approach for transonic aeroelasticity studies called the direct coupling method. This direct coupling is realized between the computation of aerodynamic forces and the computation of displacements. The flow is modeled by using the Transonic Small Perturbation (TSP). In steady flow, we determine the static deformations of the structure. The strong coupling insures the equilibrium state between the aerodynamic forces and the static deformations and in the steady flow between the aerodynamic and the aeroelastic forces in the time domain. The analysis of the resulting displacements give the evolution of the structural modes and enable us to detect flutter. Numerical results are presented for a civil aircraft and are compared with other methods in the frequency domain. Author

N92-27955*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

INVESTIGATION OF THE AEROELASTIC STABILITY OF THE AFW WIND-TUNNEL MODEL USING CAP-TSD

WALTER A. SILVA and ROBERT M. BENNETT *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 11 p (SEE N92-27936 18-02) Mar. 1992 Previously announced as N92-11977

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

The Computational Aeroelasticity Program - Transonic Small Disturbance (CAP-TSD) code is applied to the Active Flexible Wing (AFW) wind tunnel model for prediction of the model's transonic aeroelastic behavior. A semi-span computational model is used for evaluation of symmetric motions and a full span model is used for evaluation of antisymmetric motions. Static aeroelastic solutions using CAP-TSD are computed. Dynamic flutter analyses are then performed as perturbations about the static aeroelastic deformations and presented as flutter boundaries in terms of Mach number and dynamic pressure. Flutter boundaries that take into account modal refinements, vorticity, and entropy corrections, antisymmetric motions and sensitivity to the modeling of the wing tip ballast stores are also presented and compared with experimental flutter results. Author

N92-27957*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

TRANSONIC AEROELASTIC COMPUTATIONS ON WINGS USING NAVIER-STOKES EQUATIONS

GURU P. GURUSWAMY and SHIGERU OBAYASHI *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 22 p (SEE N92-27936 18-02) Mar. 1992

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

Aeroelastic computations are made on fighter type wings in the transonic regime. The flow is modeled using the Navier-Stokes equations and is coupled with structural equations of motion. The flow equations are solved by a time accurate finite difference scheme with moving grids. The coupled aeroelastic equations of motion are solved using the linear acceleration method. The configuration adaptive dynamic grids are time-accurately generated using the aeroelastically deformed shape of the wing. Computations are made for oscillating rigid wings with moving shock waves in the presence of leading edge vortices. The computed results compare well with the experiment. Unsteady computations are made to demonstrate the shock-vortex interaction phenomenon on wings in ramp motion. Effects of flexibility and pitch rate are demonstrated for flows with vortices. Author

N92-27959# General Dynamics Corp., Fort Worth, TX.

TRANSONIC WIND TUNNEL INVESTIGATION OF LIMIT CYCLE OSCILLATIONS ON FIGHTER TYPE WINGS

ATLEE M. CUNNINGHAM, JR. (General Dynamics Corp., Fort Worth, TX.) and RUUD G. DENBOER (National Aerospace Lab., Amsterdam, Netherlands) *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 14 p (SEE N92-27936 18-02) Mar. 1992

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A wind tunnel investigation was conducted to investigate the unsteady aerodynamic aspects of transonic Limit Cycle Oscillations (LCO) on fighter type aircraft wings. The first test, conducted with a wing body configuration with wing stores, was restricted to incidences below 10 deg. Test results are presented with the objective of obtaining unsteady pressure and forces necessary for identifying the aerodynamic nature of transonic LCO which is currently encountered on many fighter configurations. The wing panel was oscillated in pitch at amplitudes and frequencies typical of LCO for flow conditions in which significant shock-induced separation is encountered. Unsteady pressure data were obtained for the wing panel in terms of both harmonic components and time-histories to highlight the nonlinearities. Unsteady forces and moments measured on the wing panel as well as on each wing store were also obtained to indicate the level of contribution of each element to the overall unsteady wing loads for pitching motions. Author

N92-27960*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

THE BENCHMARK AEROELASTIC MODELS PROGRAM: DESCRIPTION AND HIGHLIGHTS OF INITIAL RESULTS

ROBERT M. BENNETT, CLINTON V. ECKSTROM, JOSE A. RIVERA, JR., BRYAN E. DANSBERRY, MOSES G. FARMER, and MICHAEL H. DURHAM *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 11 p (SEE N92-27936 18-02) Mar. 1992 Previously announced as N92-15049

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An experimental effort was implemented in aeroelasticity called the Benchmark Models Program. The primary purpose of this program is to provide the necessary data to evaluate computational fluid dynamic codes for aeroelastic analysis. It also focuses on increasing the understanding of the physics of unsteady flows and providing data for empirical design. An overview is given of this program and some results obtained in the initial tests are highlighted. The tests that were completed include measurement of unsteady pressures during flutter of a rigid wing with an NACA 0012 airfoil section and dynamic response measurements of a

flexible rectangular wing with a thick circular arc airfoil undergoing shock boundary layer oscillations. Author

N92-27961# Queens Univ., Belfast (United Kingdom).
FURTHER INVESTIGATION OF THE EFFECT OF MODEL COOLING ON PERIODIC TRANSONIC FLOW
S. RAGHUNATHAN (Queens Univ., Belfast (Northern Ireland).), F. ZARIFI-RAD (Queens Univ., Belfast (Northern Ireland).), and D. G. MABEY (Royal Aerospace Establishment, Bedford, England) *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 13 p (SEE N92-27936 18-02) Mar. 1992
(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04
An experimental investigation of the effect of model cooling on transonic periodic flows on biconvex airfoils is reported. The test conditions included shock interactions with laminar and turbulent boundary layers at a Reynolds number of 0.9 million and model wall temperature to tunnel total temperature ratios 0.5 to 1.0. The results show large effects of model cooling on transonic periodic flows. The effects observed are thought to correspond to what would happen at high Reynolds numbers at adiabatic wall temperatures. Author

N92-27962# Royal Aerospace Establishment, Bedford (England). Aerodynamics Dept.
A REVIEW OF SCALE EFFECTS ON SURFACES IN UNSTEADY MOTION
D. G. MABEY *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 19 p (SEE N92-27936 18-02) Mar. 1992
(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04
The importance of scale effects is recognized generally in steady aerodynamics but is often ignored in unsteady aerodynamics. An attempt is made to remedy this situation by the compilation of a review of information on the influence of Reynolds number from a wide range of unsteady aerodynamic tests, with particular reference to wing flows. The unsteady tests considered here relate to surfaces in unsteady motion and include dynamic tests of airfoils and wings, pressure measurements, oscillatory control surface derivatives, and stability derivatives. Here, it is suggested that for the recommended model conditions with fixed transition, scale effects are small for fully attached or well-separated flows, but may be close to incipient separation. With fixed transition, extrapolation from model to full-scale Reynolds numbers is usually possible. In contrast, with free transition, scale effects can be large for both attached and separated flows, and extrapolation from model to full-scale Reynolds numbers is usually extremely difficult. Some test cases for the prediction of scale effects in unsteady aerodynamics are suggested. Author

N92-30947# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
VORTEX FLOW AERODYNAMICS [L'AERODYNAMIQUE DES ECOULEMENTS TOURBILLONNAIRES]
J. H. B. SMITH (Royal Aircraft Establishment, Farnborough, England), J. F. CAMPBELL (National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.), and A. D. YOUNG, ed. Apr. 1992 27 p Presented at the Fluid Dynamics Panel Symposium, Scheveningen, The Netherlands, 1-4 Oct. 1990
(AGARD-AR-299; ISBN-92-835-0670-7) Copyright Avail: CASI HC A03/MF A01
The principal emphasis of the meeting was to be on the understanding and prediction of separation-induced vortex flows and their effects on vehicle performance, stability, control, and structural design loads. This report shows that a substantial amount of the papers covering this area were received from a wide range of countries, together with an attendance that was even more diverse. In itself, this testifies to the current interest in the subject and to the appropriateness of the Panel's choice of topic and approach. An attempt is made to summarize each paper delivered, and to relate the contributions made in the papers and in the discussions to some of the important aspects of vortex flow aerodynamics. This reveals significant progress and important clarifications, but also brings out remaining weaknesses in predictive capability and gaps in understanding. Where possible, conclusions are drawn and areas of continuing concern are identified. Author

N93-13205# National Aerospace Lab., Amsterdam (Netherlands).
AERODYNAMIC ANALYSIS OF SLIPSTREAM/WING/NACELLE INTERFERENCE FOR PRELIMINARY DESIGN OF AIRCRAFT CONFIGURATIONS
C. M. VANBEEK, W. J. PIERS, and B. OSKAM *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 20 p (SEE N93-13199 03-34) Sep. 1992
Sponsored by Netherlands Agency for Aerospace Programs
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04
A panel method based model for the computation of the time-averaged influence of a propeller slipstream on the aerodynamic characteristics of an aircraft configuration is described. The slipstream model is based on the simplifications that the single-rotating propeller is replaced by an actuator disk and that all the vorticity of the slipstream is represented on a cylindrical sheet of fixed geometry which envelops the slipstream in combination with a discrete vortex at the axis of the slipstream. Appropriate jump conditions across the actuator disk and boundary conditions on the cylindrical sheet, solved simultaneously with the boundary conditions on the aircraft configuration, yield the mutual influence of the propeller and the slipstream on the aerodynamic characteristics of the aircraft configuration. This slipstream model is incorporated in a three-dimensional panel method. Computed lift increments due to the slipstream are presented for a realistic wing/nacelle/fuselage-configuration and compared with wind-tunnel data for several thrust coefficients and angles of attack of the aircraft. Author

N93-13214# Alenia Aeronautica, Turin (Italy). Defence Aircraft Div.
MASS FLOW EFFECTS ON THE LOW SPEED CHARACTERISTICS OF AN ADVANCED COMBAT AIRCRAFT
E. BARBANTINI, A. FERRETTI, and A. GATTI *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 7 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A02/MF A04
The experimental results obtained on a low speed six components wind tunnel model representative of a delta-canard configuration and featuring an ejector based internal flow augmentation system are described in order to outline at what extent the near field distortions induced by the intake operating conditions can modify the aircraft aerodynamic stability characteristics and foreplane control effectiveness. Author

N93-13221# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany).
COMPARATIVE PERFORMANCE TESTS OF A PITOT-INLET IN SEVERAL EUROPEAN WIND-TUNNELS AT SUBSONIC AND SUPERSONIC SPEEDS
P.-A. MACKRODT, E. L. GOLDSMITH (Aircraft Research Association Ltd., Bedford, England), I. MCGREGOR (Royal Aircraft Establishment, Bedford, England), J. LEYNAERT (Office National d'Etudes et de Recherches Aerospatiales, Paris, France), F. GARCON (Office National d'Etudes et de Recherches Aerospatiales, Modane, France), and J. BRILL (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany) *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 14 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04
A common design of inlet model (RAE Model 742L Cowl 2), but built to slightly different scales (convenient to the specific wind tunnel), was investigated in the RAE 8 ft x 8 ft tunnel, the ONERA S2MA-tunnel (1.75 m x 1.77 m), and the transonic 1 m x 1 m wind tunnel (TWG) of DLR. The measurements were carried out at subsonic and supersonic Mach numbers, at several Reynolds numbers and angles of attack. The paper presents--aside of a short description of the wind tunnels and the models--details of the instrumentation and the formulae used to calculate the steady-state and the instantaneous distortion parameters. A brief description of the data acquisition and reduction systems is also given. Results of the three tests are presented in the usual format, and from the comparison of the results the differences are analyzed and the main origins of the discrepancies discussed and explained. Finally some recommendations are given for reducing those discrepancies in further tests. Author

N93-13222# Aerospatiale, Verrieres-L-Buisson (France). Div. Engins Tactiques.
AERODYNAMIC STUDIES OF SUPERSONIC AIR INTAKES [ETUDES AERODYNAMIQUES DE PRISES D'AIR SUPERSONIQUES]
P. GARNERO and R. G. LACAU *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 16 p (SEE N93-13199 03-34) Sep. 1992 In FRENCH
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

The Tactical Missile Division has been using ramjets on its missiles for more than thirty years. The adaptation of this type of propulsion to very high speed aircraft and airbreathing launchers is investigated. We must study vehicles designed for higher and higher speeds, and we need to optimize more rapidly, and at a lower cost, our airbreathing missile configurations. We completed our supersonic air intake design methodology by using CFD for our work in external and internal aerodynamics. These CFD tools involving Euler and Navier-Stokes codes and mesh generators are complementary to wind tunnel tests. Author

N93-13223# Nangia Associates, Bristol (England).
APPLICATION OF SUBSONIC FIRST-ORDER PANEL METHODS FOR PREDICTION OF INLET AND NOZZLE AERODYNAMIC INTERACTIONS WITH AIRFRAME
R. K. NANGIA and M. E. PALMER *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 16 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

Modern aircraft require intake and nozzle flows to be closely integrated with the airframe, and various layouts are possible. In some cases, the intake/nozzle is integral with the fuselage providing a relatively 'compact' layout. This contrasts with configurations in which the nacelles are displaced from the fuselage but are near lifting surfaces. Engine intake flow conditions may range from very high Mass Flow Ratio (MFR) at take-off, to very low MFR on approach, and may include zero MFR during inflight shut-downs. The effect of the intake flows on adjacent components will vary with intake MFR, aircraft attitude, and Mach number. Designers need to know the magnitude of these effects to ensure that they can be contained to satisfactory levels within the available control parameters. A first-order panel method was used to analyze the MFR effects on several configurations. These range from simple 'generic' types to complex, Canard-Delta configurations and include various intake and nozzle arrangements. Mach number and asymmetric effects were studied in particular cases. Author

N93-19921# Industrie Aeronautiche e Meccaniche Rinaldo Piaggio S.p.A., Genoa (Italy).
NATURAL LAMINAR FLOW TEST IN-FLIGHT VISUALIZATION
G. SACCO, P. CINQUETTI, and S. MARTINI *In* AGARD, Flight Testing 8 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A02/MF A04

This paper presents an overview of the test campaign performed on the Piaggio P.180 'Avanti' aircraft in order to develop and obtain the maximum natural laminar flow on the lifting surfaces. The paper reports the development of new profile family that could allow not only good laminarity flow characteristics in the aircraft flight envelope but also favorable pressure distribution and performance results. The wind tunnel and in-flight visualization as well as the effects of natural laminar flow airfoil contamination are herein described. Sublimating chemicals techniques have been employed to test the design airfoils even if this approach allowed only one test point per flight. Positive results were however achieved and demonstrated the positive effects of such a design philosophy. Author

N93-19922# Calspan Corp., Arnold AFS, TN. Arnold Engineering Devlopment Center.
A TECHNIQUE FOR PREDICTING AIRCRAFT FLOW-FIELD EFFECTS UPON AN UNGUIDED BOMB BALLISTIC TRAJECTORY AND COMPARISON WITH FLIGHT TEST RESULTS
H. PASCHALL MASSENGILL, JR. *In* AGARD, Flight Testing 12 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

Accurate aircraft delivery of unguided munitions requires that an aircraft onboard targeting algorithm account for the free-stream drag characteristics of a released store as well as the effects of ejection forces and aircraft-induced aerodynamic flow-field transients. Of the three, aerodynamic flow-field effects are the most difficult to predict. The current state of weapon delivery technology requires that many hours of flight testing be conducted and the test data analyzed to form a significant foundation upon which to build an accurate flow-field compensation algorithm. The proposed use of ground simulation techniques in lieu of flight test techniques to achieve accurate aircraft delivery of unguided weapons is the thesis of this paper. A method was developed to permit application of ground simulation techniques to the challenging arena of aircraft weapon delivery accuracy. The method was tested by correcting a flow-field compensation algorithm for a typical supersonic tactical aircraft and comparing the resultant aircraft bombing accuracy with that attained using traditional state-of-the-art flight testing techniques. Preliminary results indicate that good aircraft bombing accuracy can be achieved using only ground simulation techniques. Success of the method offers the potential to reduce the cost of producing an accurate aircraft weapon delivery algorithm by an order of magnitude and the time required by three-fourths. Planned future efforts will attempt to expand method validity into increasingly demanding regions of the flight envelope. Author

N94-10421# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
THEORETICAL AND EXPERIMENTAL METHODS IN HYPERSONIC FLOWS [LES METHODES THEORIQUES ET EXPERIMENTALES POUR L'ETUDE DES ECOULEMENTS HYPERSONIQUES]
Apr. 1993 575 p Symposium held in Torino, Italy, 4-8 May 1992 Original contains color illustrations
(AGARD-CP-514; ISBN-92-835-0694-4; AD-A267032) Copyright Avail: CASI HC A24/MF A04

Papers prepared for the AGARD Fluid Dynamics Panel Symposium on theoretical and experimental methods in hypersonic flows held on 4-8 May 1992 are presented. The objectives of the Symposium were to (1) report and assess the advances being made by the AGARD community on the development and application of theoretical methods and experimental techniques for simulating hypersonic flows over aerospace vehicles; (2) highlight outstanding problem areas; and (3) establish pointers to aid in the planning and implementation of future research programs. Major topics covered by the Symposium were testing techniques and instrumentation, computational methods and physical modeling, and validation and accuracy assessment. For individual titles, see N94-10422 through N94-10465.

N94-10422*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CFD ANALYSIS OF HYPERSONIC, CHEMICALLY REACTING FLOW FIELDS
T. A. EDWARDS *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 12 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

Design studies are underway for a variety of hypersonic flight vehicles. The National Aero-Space Plane will provide a reusable, single-stage-to-orbit capability for routine access to low earth orbit. Flight-capable satellites will dip into the atmosphere to maneuver to new orbits, while planetary probes will decelerate at their destination by atmospheric aerobraking. To supplement limited experimental capabilities in the hypersonic regime, computational fluid dynamics (CFD) is being used to analyze the flow about these configurations. The governing equations include fluid dynamic as well as chemical species equations, which are being solved with new, robust numerical algorithms. Examples of CFD applications to hypersonic vehicles suggest an important role this technology will play in the development of future aerospace systems. The computational resources needed to obtain solutions are large, but solution adaptive grids, convergence acceleration, and parallel processing may make run times manageable. Author

N94-10427*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
IN-FLIGHT EVALUATION OF AERODYNAMIC PREDICTIONS OF AN AIR-LAUNCHED SPACE BOOSTER
ROBERT E. CURRY, MICHAEL R. MENDENHALL (Nielsen Engineering and Research, Inc., Mountain View, CA.), and BRYAN MOULTON (PRC Kentron, Inc., Edwards, CA.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 18 p (SEE N94-10421 01-02) Apr. 1993 Sponsored in part by DARPA and Orbital Sciences Corp.
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04
Several analytical aerodynamic design tools that were applied to the Pegasus air-launched space booster were evaluated using flight measurements. The study was limited to existing codes and was conducted with limited computational resources. The flight instrumentation was constrained to have minimal impact on the primary Pegasus missions. Where appropriate, the flight measurements were compared with computational data. Aerodynamic performance and trim data from the first two flights were correlated with predictions. Local measurements in the wing and wing-body interference region were correlated with analytical data. This complex flow region includes the effect of aerothermal heating magnification caused by the presence of a corner vortex and interaction of the wing leading edge shock and fuselage boundary layer. The operation of the first two missions indicates that the aerodynamic design approach for Pegasus was adequate, and data show that acceptable margins were available. Additionally, the correlations provide insight into the capabilities of these analytical tools for more complex vehicles in which design margins may be more stringent. Author

N94-10433*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RECOMMENDATIONS FOR FUTURE RESEARCH IN HYPERSONIC INSTRUMENTATION
S. L. OCHELTREE *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 2 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A01/MF A04
An overview of the NATO Advanced Research Workshop is presented. It describes the process followed to obtain a group consensus on the main technical recommendations for each of the five technical sessions of the Workshop and presents the general conclusions and recommendations for future research agreed upon by the workshop participants. Author (revised)

N94-10434*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LOCAL MEASUREMENT OF TEMPERATURES AND CONCENTRATIONS: A REVIEW FOR HYPERSONIC FLOWS
C. DANKERT (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany.), R. CATTOLICA (California Univ., San Diego.), and W. SELLERS *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 10 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A02/MF A04
The quality of reentry simulation for Shuttle, HERMES, Sanger, and NASP systematically suffers from the strong non-equilibrium of rotational and vibrational temperature due to the rapid acceleration of the test gas in the nozzle. Therefore the determination of temperatures is necessary and, if possible, preferable by a non-intrusive technique. The specific interests of this review are optical techniques such as electron beam fluorescence, laser-induced fluorescence, and coherent anti-Stokes Raman scattering. The capabilities available for local measurements with temporal resolution and quantitative accuracy are discussed for velocity, temperature, density, species concentrations, and fluctuations due to turbulence. The applicability of these methods of measurement is presented and discussed for the coming topic in aerothermodynamics: experimental techniques of hot gases in high enthalpy flows. Author

N94-10435*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PRESSURE AND FORCE MEASUREMENTS ON MODELS SET IN HYPERSONIC FLOWS: A REVIEW
CHARLES G. MILLER *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 11 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04
A review of measurement techniques used to obtain aerodynamic forces and moments and surface/flow field pressures for models tested in impulse hypersonic-hypervelocity facilities and in conventional-type hypersonic wind tunnels is presented. Although force and moment measurement techniques presently used in hypersonic wind tunnels are relatively unchanged from the 1960's and 1970's, significant advances have recently been made for impulse facilities. For both hypersonic wind tunnels and impulse facilities, the state-of-the-art has advanced via refinements, improved test techniques, and advances in semiconductor technology, data acquisition systems, and computers. The introduction of electronically scanned pressure systems over a decade ago 'revolutionized' pressure measurements in hypersonic wind tunnels and a second 'revolution' is impending with the development and application of optical, two-dimensional, global pressure measurement techniques. The development and continued refinement of miniature piezoresistive transducers has provided the capability to perform detailed surface pressure measurements on relatively small, complex models in impulse facilities; these transducers also provided the capability for intrusive flow field pressure measurements with miniature survey rakes. Author (revised)

N94-10436# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
VELOCITY MEASUREMENTS IN HYPERSONIC FLOWS: A REVIEW
ALAIN BOUTIER, WILLIAM J. YANTA (Naval Surface Weapons Center, Silver Spring, MD.), and GUNTER SMEETS (Institut Franco-Allemand de Recherches, Saint-Louis, France.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 9 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A02/MF A04
With the renewed interest in hypersonics, there is a real need for accurate, detailed measurements of fluid flow and thermodynamic properties of high speed, high temperature flows. An analysis of the different means to measure the velocity is done; the relative merits of the particle based and the molecular based methods are evaluated, leading to a set of recommendations for future research. Papers presented at the NATO Advanced Research Workshop are reviewed and summarized. Derived from text

N94-10440# Institut National de Recherche d'Informatique et d'Automatique, Valbonne (France).
SYNTHESIS OF THE WORKSHOP ON HYPERSONIC FLOWS FOR REENTRY PROBLEMS
REMI ABGRALL, JEAN-ANTOINE DESIDERI, MICHEL MALLET (Avions Marcel Dassault, Saint-Cloud, France.), JACQUES PERIAUX (Avions Marcel Dassault, Saint-Cloud, France.), PIERRE PERRIER (Avions Marcel Dassault, Saint-Cloud, France.), and BRUNO STOUFFLET (Avions Marcel Dassault, Saint-Cloud, France.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 23 p (SEE N94-10421 01-02) Apr. 1993 Workshop held in Antibes, France, Jan. 1990 and Apr. 1991
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04
One of the most challenging problems of modern aerospace engineering is undoubtedly the prediction of hypersonic flows around reentry vehicles. Indeed this challenge has many aspects: defining the appropriate physical model for these flows is the first difficulty since very complex physical and chemical phenomena take place during the reentry phase; moreover, temperature, velocity, and enthalpy are very high, density very low, making the reentry conditions very difficult to reproduce in ground-based experiments. Thus, in the past two decades, important efforts in computational fluid dynamics have been made employing supercomputers to simulate these complex flows. However, most simulation tools were originally designed for transonic or supersonic flow applications and later extended; these usually contain imperfect models, and also still have to be improved to permit

the accurate prediction of hypersonic flows. This situation has motivated strong international cooperative efforts including three Europe/US Short Courses on Hypersonics and two sessions (Part 1 and 2) of the scientific workshop organized by INRIA and GAMNI which took place in Antibes, France. Part 1 brought together a group of experts active in hypersonics, and promoted direct comparisons of codes and experiments. The main objective of part 2 was to improve the quality of both experimental and computational results, and evaluate numerical codes by code-to-code or code-to-experiment comparisons, and permit a better confidence in the prediction tools to be used in the design of hypersonic vehicles. The presentation is aimed at reporting the main conclusions as they were expressed at the meeting by experts, including some of their recommendations regarding the validation of numerical codes. Derived from text

N94-10442# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
FLOW DEVELOPMENT IN A CIRCULAR PIPE IN THE UTIAS/RPI M = 8.3 GUN TUNNEL
J. P. SISLIAN, Z. HE, and R. L. DESCHAMBAULT *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 13 p (SEE N94-10421 01-02) Apr. 1993 Sponsored in part by Natural Sciences and Engineering Research Council
(Contract(s)/Grant(s): F33615-87-C-2748)
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04
The investigation is concerned with the understanding of the structure of the hypersonic flow developed in a circular pipe. The experiments were conducted in the University of Toronto Institute for Aerospace Studies (UTIAS)/Ryerson Polytechnical Institute (RPI) gun tunnel at a freejet Mach number of 8.30 and Reynolds number based on the pipe diameter, Re = 2.44 x 10(exp 6). Wall static pressure, as well as in-stream static and pitot pressure measurements at several sections in the pipe, shed some light into the physical nature of the considered flow. The measurements indicate that shocks generated in the pipe flow are primarily oblique. Measurements near the pipe axis and in wave structures presented some difficulties. Further work is needed to clarify certain features of the investigated flow. The presented results may guide the development of computational fluid dynamic codes applicable to hypersonic pipe flows. Author (revised)

N94-10443# Wright Lab., Wright-Patterson AFB, OH.
EXPERIMENTAL AND COMPUTATIONAL COMPARISONS OF MACH 6 HIGH REYNOLDS NUMBER HEAT TRANSFER AND SKIN FRICTION
LELLO GALASSI and NORMAN E. SCAGGS *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 14 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04
Wind tunnel measurements on a flat plate, ogive cylinder, and a compression ramp at zero angle-of-attack are compared to computational fluid dynamics (CFD) predictions of the flow parameters. These models provide a zero-pressure gradient, favorable-pressure gradient, and an adverse-pressure gradient flow condition, respectively. Results are presented for surface pressure and temperature distributions, boundary layer surveys, heat transfer rates, and local skin friction coefficients. Test conditions were varied over a free-stream Reynolds number range of 0.45-9.1 (10 exp 7) per meter, at a nominal Mach number of 6. Wind tunnel measurements on the three models were made using static pressure ports, embedded thermocouples, coaxial heat transfer gauges, slug calorimeters, Preston tube skin friction devices, and skin friction force balances. Boundary layer profiles were measured with total temperature and pitot pressure probes and with laser doppler velocimetry. Parabolized Navier-Stokes and full Navier-Stokes code predictions of the measured parameters are compared to experimental measurements. Results indicate surface pressure distributions are easily predicted by the CFD codes used and for the simple geometries modeled. For CFD codes which predict the surface heat transfer rate accurately, the local skin friction coefficient agrees to within 7-10 percent of the measured data for favorable-pressure gradient and zero-pressure gradient configurations. For adverse-pressure gradients, the code used did not predict skin friction values accurately, although heat transfer predictions matched the data. Large gradients in the hypersonic boundary layer require dense grids near the model surface in order for CFD codes to accurately predict the surface heat transfer rate and the local skin friction coefficient. Additionally, dense grids in the streamwise direction are necessary to properly resolve the boundary layer for adverse-pressure gradients. Author (revised)

N94-10444# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
EXPERIMENTAL, ANALYTICAL, AND COMPUTATIONAL METHODS APPLIED TO HYPERSONIC COMPRESSION RAMP FLOWS
G. SIMEONIDES, W. HAASE (Dornier Luftfahrt G.m.b.H., Friedrichshafen, Germany.), and M. MANNA *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 12 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04
Experimental data on fully laminar and transitional shock wave boundary layer interactions in two-dimensional compression corners are provided and used for the validation of two full Navier-Stokes solvers, as well as for checking the capabilities and limitations of simple analytical prediction methods. Viscous pressure interaction, free interaction, and inviscid oblique shock theory are found to predict well the pressure levels on the flat plate upstream of the interaction, within the separated region and downstream of the interaction, respectively. The reference temperature theory is found to perform well in attached flow regimes both upstream and downstream of the interaction region, and to provide the basis for a universal peak heating correlation law. Full Navier-Stokes computations are necessary, however, to predict the extent of the interaction region and the associated influence upon the pressure distribution (control effectiveness) as well as the detailed heat transfer distribution. To achieve this, very fine gridding coupled with the use of strict convergence criteria (based on the evolution of the location of the separation point rather than on standard density residuals) is shown to be necessary. It is finally shown that, although sophisticated turbulence models need to be further developed before the detailed characteristics of fully turbulent shock wave boundary layer interactions may be predicted, transitional interactions (where transition typically occurs in the neighborhood of reattachment) may be adequately handled by algebraic turbulence models 'switched on' just downstream of reattachment. Author

N94-10445# Sandia National Labs., Albuquerque, NM. Aerodynamics Dept.
JOINT COMPUTATIONAL AND EXPERIMENTAL AERODYNAMIC RESEARCH ON A HYPERSONIC VEHICLE
WILLIAM L. OBERKAMPF, DANIEL P. AESCHLIMAN, and MARY MCWHERTER WALKER *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 11 p (SEE N94-10421 01-02) Apr. 1993
(Contract(s)/Grant(s): DE-AC04-76DP-00789)
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04
A closely coupled computational and experimental aerodynamics research program was conducted on a hypersonic vehicle configuration at Mach 8. Aerodynamic force and moment measurements and flow visualization results were obtained in the Sandia National Laboratories hypersonic wind tunnel for laminar boundary layer conditions. Parabolized and iterative Navier-Stokes simulations were used to predict flow fields and forces and moments on the hypersonic configuration. The basic vehicle configuration is a spherically blunted 10 deg cone with a slice parallel with the axis of the vehicle. On the slice portion of the vehicle, a flap can be attached; flap deflection angles of 10 deg, 20 deg, and 30 deg were used. Comparisons are made between experimental and computational results to evaluate the quality of each and to identify areas where improvements are needed. This extensive set of high-quality experimental force and moment measurements is recommended for use in the calibration and validation of computational aerodynamics codes.
Author (revised)

N94-10446*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ISSUES AND APPROACH TO DEVELOP VALIDATED ANALYSIS TOOLS FOR HYPERSONIC FLOWS: ONE PERSPECTIVE
GEORGE S. DEIWERT *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 10 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A02/MF A04

Critical issues concerning the modeling of low density hypervelocity flows where thermochemical nonequilibrium effects are pronounced are discussed. Emphasis is on the development of validated analysis tools, and the activity in the NASA Ames Research Center's Aerothermodynamics Branch is described. Inherent in the process is a strong synergism between ground test and real gas computational fluid dynamics (CFD). Approaches to develop and/or enhance phenomenological models and incorporate them into computational flowfield simulation codes are discussed. These models were partially validated with experimental data for flows where the gas temperature is raised (compressive flows). Expanding flows, where temperatures drop, however, exhibit somewhat different behavior. Experimental data for these expanding flow conditions is sparse and reliance must be made on intuition and guidance from computational chemistry to model transport processes under these conditions. Ground based experimental studies used to provide necessary data for model development and validation are described. Included are the performance characteristics of high enthalpy flow facilities, such as shock tubes and ballistic ranges. Author (revised)

N94-10447# Manchester Univ. (England). Dept. of Engineering.
COMPARISON OF COMPUTATION AND EXPERIMENT FOR A HIGH ENTHALPY, HEATED-DRIVER, SHOCK-TUBE ENVIRONMENT
S. SHAHPAR, A. KENNAUGH, I. M. HALL, and D. I. A. POLL *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 26 p (SEE N94-10421 01-02) Apr. 1993 Sponsored by British Aerospace Aircraft Group
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A coordinated computational and experimental study was made of blunt-body flows with nonequilibrium chemistry. The temperature range was such that significant dissociation of oxygen was expected but very little dissociation of nitrogen. Both pure oxygen, O2 and O, and air, treated computationally using a five species (O2, N2, NO, N, and O) model were studied. Results obtained using different published values of the chemical rate coefficients were compared and assessed for a model problem. The effects of size (i.e., Damkohler number) and freestream velocity were also investigated. The flow computations used an explicit timemarching method based on a TVD version of the MacCormack predictor-corrector scheme. A point implicit TVD method was developed to deal with the stiffness problems introduced by the finite rate chemistry. Interferograms of the flow obtained in a shock tunnel are compared with the computational results. The bow shock wave shape and the shock detachment which are dependent on the degree of chemical reaction and thermal excitation of the gas show that the calculation method is promising. Author (revised)

N94-10449*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THREE-DIMENSIONAL HYPERSONIC RAREFIED FLOW CALCULATIONS USING DIRECT SIMULATION MONTE CARLO METHOD
M. CEVDET CELENLIGIL (Middle East Technical Univ., Ankara, Turkey.) and JAMES N. MOSS *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 12 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

A summary of three-dimensional simulations on the hypersonic rarefied flows in an effort to understand the highly nonequilibrium flows about space vehicles entering the Earth's atmosphere for a realistic estimation of the aerothermal loads is presented. Calculations are performed using the direct simulation Monte Carlo method with a five-species reacting gas model, which accounts for rotational and vibrational internal energies. Results are obtained for the external flows about various bodies in the transitional flow regime. For the cases considered, convective heating, flowfield structure and overall aerodynamic coefficients are presented and comparisons are made with the available experimental data. The agreement between the calculated and measured results are very good. Author (revised)

N94-10450# Ohio State Univ., Columbus, OH. Dept. of Mechanical Engineering.
STABILITY OF HYPERSONIC FLOW OVER A BLUNT BODY
THORWALD HERBERT and VAHID ESFAHANIAN (DynaFlow, Inc., Columbus, OH.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 12 p (SEE N94-10421 01-02) Apr. 1993
(Contract(s)/Grant(s): F49620-87-K-0005; F49620-88-C-0082)
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

A numerical method was developed to compute the axisymmetric flow over blunt slender bodies with high accuracy to enable reliable analysis of the stability properties. The flow field is obtained using the Beam-Warming method to solve the thin-layer Navier-Stokes equations. The code was thoroughly validated and applied to compute the laminar flow over a long blunt cone with 7 deg half-angle at M(sub infinity) = 8. The linear stability of this flow was analyzed with highly accurate finite-difference and spectral methods. The results are compared with previous numerical studies and the experimental data of Stetson et al. Author (revised)

N94-10451*# Arizona State Univ., Tempe, AZ. Dept. of Mechanical and Aerospace Engineering.
STABILITY OF HYPERSONIC BOUNDARY-LAYER FLOWS WITH CHEMISTRY
HELEN L. REED, GREGORY K. STUCKERT, and TIMOTHY S. HAYNES *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 13 p (SEE N94-10421 01-02) Apr. 1993 Sponsored by NASA. Langley Research Center; NASA. Ames Research Center; NSF; McDonnell-Douglas Corp.; and General Dynamics/Fort Worth
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The effects of nonequilibrium chemistry and three dimensionality on the stability characteristics of hypersonic flows are discussed. In two-dimensional (2-D) and axisymmetric flows, the inclusion of chemistry causes a shift of the second mode of Mack to lower frequencies. This is found to be due to the increase in size of the region of relative supersonic flow because of the lower speeds of sound in the relatively cooler boundary layers. Although this shift in frequency is present in both the equilibrium and nonequilibrium air results, the equilibrium approximation predicts modes which are not observed in the nonequilibrium calculations (for the flight conditions considered). These modes are superpositions of incoming and outgoing unstable disturbances which travel supersonically relative to the boundary-layer edge velocity. Such solutions are possible because of the finite shock stand-off distance. Their corresponding wall-normal profiles exhibit an oscillatory behavior in the inviscid region between the boundary-layer edge and the bow shock. For the examination of three-dimensional (3-D) effects, a rotating cone is used as a model of a swept wing. An increase of stagnation temperature is found to be only slightly stabilizing. The correlation of transition location (N = 9) with parameters describing the crossflow profile is discussed. Transition location does not correlate with the traditional crossflow Reynolds number. A new parameter that appears to correlate for boundary-layer flow was found. A verification with experiments on a yawed cone is provided. Author (revised)

N94-10452# Manchester Univ. (England). Dept. of Engineering.
REAL GAS AND SURFACE TRANSPIRATION EFFECTS UPON SWEPT LEADING EDGE HIGH SPEED FLOW INCLUDING TRANSITION
D. I. A. POLL *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 16 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

The extension of simple methods for the prediction of skin friction and heat transfer at an infinite-swept attachment line to cover the hypervelocity flight regime including the effects of surface transpiration is considered. The analysis is limited to the situation where the flow is in thermochemical equilibrium everywhere. Real gas effects are identified and their influence is quantified. The importance of freestream conditions and attachment-line inclination are assessed. Consideration is also given to the issue of boundary layer transition. Author (revised)

N94-10453# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany). Inst. of Theoretical Fluid Mechanics.

ON THE INSTABILITY OF HYPERSONIC FLOW PAST A POINTED CONE: COMPARISON OF THEORETICAL AND EXPERIMENTAL RESULTS AT MACH 8

MARTIN SIMEN (Dornier Luftfahrt G.m.b.H., Friedrichshafen, Germany.) and UWE DALLMANN *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 13 p (SEE N94-10421 01-02) Apr. 1993 Sponsored in part by BMFT

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In view of the prevailing discrepancies between experiment and theory with regard to instabilities in hypersonic flow, an extended theoretical approach is studied. For hypersonic flow past a pointed cone Thin Layer Navier Stokes solutions are compared to similarity solutions with different modeling of viscosity-temperature laws. The formulation of the stability equations in curvilinear coordinates allows a discussion of various representations of the local body metric. A systematic sensitivity study of basic state profiles and spatial amplification rates is performed. It is found that the improved agreement with the experiment in the viscous first mode region is equally due to the extended stability analysis, where cone metric is specified, and the extended mean flow solution as well. In the second mode region the major improvement results from the more complete basic state formulation, however, the close agreement with measured growth rates is only achieved when the stability analysis is based on conical metric. Author (revised)

N94-10454# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.

STUDIES OF HYPERSONIC VISCOUS FLOWS

R. HILLIER, D. C. KIRK, M. SELL, and S. SOLTANI *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 11 p (SEE N94-10421 01-02) Apr. 1993 Sponsored in part by Defence Research Agency

(Contract(s)/Grant(s): SRC-GR/G/57277)

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Results from current studies on slender bodies of revolution tested at a nominal Mach number of 9 are presented. It concentrates on the case of a spherically-blunted cone, providing kinetic heating data for laminar, turbulent, and transitional flow regimes. Nose blunting exerts a powerful control on the location of transition, and the quantitative measurements of this location using thin film gauge techniques are supported by flow visualization using liquid crystal thermography. We also discuss work and plans for two other studies which are in their early stages: these are a cavity-induced separation and the development of turbulent boundary layers under controlled pressure gradients. Preliminary computations using a high resolution Navier-Stokes code are also presented. Author (revised)

N94-10455# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

CALCULATIONS OF VISCOUS NONEQUILIBRIUM FLOWS IN NOZZLES [CALCULS D'ECOULEMENTS VISQUEUX EN DESEQUILIBRE DANS DES TUYERES]

C. MARMIGNON, V. JOLY, and F. COQUEL *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 9 p (SEE N94-10421 01-02) Apr. 1993 In FRENCH Previously announced in IAA as A93-38574

(AGARD-CP-514) Copyright Avail: CASI HC A02/MF A04

An implicit finite-volume method for investigating viscous flows in a state of chemical and vibrational nonequilibrium in nozzles is presented. The ideal-fluid flux terms are calculated by a decentered Roe-type scheme that is second order in space, and the viscous fluxes are determined using a centered scheme. The numerical fluxes and the sources terms are coupled completely at the implicit stage. The proposed method is illustrated by application to two flow configurations: (1) a test case from the Antibes Workshop on hypersonic flows, and (2) a nozzle flow in the ONERA F4 wind tunnel. AIAA

N94-10456# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Lab. IUSTI/SETT.

NONEQUILIBRIUM HYPERSONIC FLOW IN A WIND-TUNNEL NOZZLE

D. ZEITOUN, E. BOCCACCIO, M. C. DRUGUET, M. IMBERT, and R. BRUN *In* AGARD. Theoretical and Experimental Methods in Hypersonic Flows 9 p (SEE N94-10421 01-02) Apr. 1993

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The interest in hypersonic flow was renewed through the Hermes European program. A better knowledge of chemical and thermodynamical nonequilibrium processes connected with aerodynamic aspects is needed to study the reentry phase of the shuttle Hermes. Around this research area, many numerical approaches, taking into account more or less complicated nonequilibrium models, were developed. In order to validate these computations, different hypersonic facilities were built or are being designed. In these facilities, the hypersonic air flow is obtained at the exit of a convergent-divergent nozzle in which the reservoir enthalpy level is such that dissociation of diatomic molecules occurs. It is of upmost importance to be able to compute the flowfield in these nozzles, in order to ascertain the upstream conditions in front of the model being studied. The aim is a numerical study of hypersonic laminar inviscid/viscous flows, taking into account, on one hand, a complete description of chemical and thermodynamical nonequilibrium processes in an inviscid flow and on the other hand, the viscous effects through solving the Navier-Stokes equations for a real gas mixture with a simplified model for the vibrational nonequilibrium effects of diatomic species. Author (revised)

N94-10457# Centro Italiano Ricerche Aerospaziali, Naples.

SOME EXPERIMENTAL STUDY AND NUMERICAL SIMULATION IN WIND TUNNEL FLOW

S. BORRELLI and E. HETTENA (Alenia Aeronautica, Torino, Italy.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 12 p (SEE N94-10421 01-02) Apr. 1993

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Some studies made during a collaboration between the Italian Aerospace Research Center (CIRA) and Alenia D.V.D., whose aim is to provide proper validation of CFD codes in hypersonic flow regime, are described. In fact, in our opinion, the combination of numerical and experimental tools should give a better theoretical understanding of such types of flow. Numerical methods able to give accurate prediction of hypersonic flows in hypersonic wind tunnels were developed and the results obtained by calculations are compared with experimental data gathered by CIRA. Alenia equilibrium three-dimensional Euler solver, originally developed to solve transonic flows and now extended to hypersonic ones, and a non-equilibrium two-dimensional Euler solver, developed by CIRA for the Hermes program, were used to get test chamber predictions. Author (revised)

N94-10460# Ecole Polytechnique Federale de Lausanne (Switzerland). Hydraulic Machines and Fluid Mechanics Inst.

HYPERSONIC MULTI BLOCK FLOW SIMULATIONS AROUND SPACE VEHICLES INCLUDING NON-EQUILIBRIUM CHEMISTRY

J. B. VOS, A. W. RIZZI (Aeronautical Research Inst. of Sweden, Bromma.), and C. M. BERGMAN (Royal Inst. of Tech., Stockholm, Sweden.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 11 p (SEE N94-10421 01-02) Apr. 1993 Sponsored in part by Commission Suisse d'Encouragement des Recherches Scientifiques

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An international collaboration on the development of multi block flow solvers using structured grids is presented. The flow equations are solved by the finite volume method using a space centered, explicit time marching scheme augmented by artificial dissipation terms. Implicit residual smoothing is used to accelerate convergence to steady state. The multi block flow solvers are written on top of the MEMCOM data base system which provides the data structure, and use a Dynamic Memory Manager to allocate the necessary storage for each block. The Euler solver EULMB can be used to simulate hypersonic flows including equilibrium and nonequilibrium air chemistry. Recently the Euler solver has been extended to solve the Navier Stokes equations for laminar caloric perfect gas flows (NSMB flow solver). Calculated results for the calculation of the flow over a double ellipsoid and over

the HERMES space shuttle are presented. The inviscid calculations around HERMES showed that if one is only interested in the aerodynamic coefficients, equilibrium air calculations are sufficient. Parallel computations showed that the communication overhead between blocks is less than 0.5 percent, showing that the multi block concept is very promising for using parallel computers efficiently. Author

N94-10461*# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.

HYPERSONIC FLOW COMPUTATIONS AROUND RE-ENTRY VEHICLES

J. PERAIRE, J. PEIRO, K. MORGAN (Wales Univ., Swansea.), M. VAHDATI, and R. C. MOLINA (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 13 p (SEE N94-10421 01-02) Apr. 1993 Sponsored in part by Dassault Aviation and British Aerospace Public Ltd. Co.

(Contract(s)/Grant(s): NAGW-1809)

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The development of an algorithm for the solution of the compressible Euler equations at high Mach numbers on unstructured tetrahedral meshes is described. The basic algorithm is constructed in the form of a central difference scheme plus an explicit added artificial viscosity based upon fourth order differences of the solution. The stability of the solution in the vicinity of strong gradients is preserved by the incorporation of an additional artificial viscosity based upon a second order difference. Higher order accuracy is regained by using the ideas of flux corrected transport to limit the amount of added viscosity. The solution is advanced to steady state by means of an explicit multi-stage time-stepping method. The computational efficiency of the complete process is improved by incorporating an unstructured multigrid acceleration procedure. A number of flows of practical interest are analyzed to demonstrate the numerical performance of the proposed approach. Author

N94-10462# Erlangen-Nuremberg Univ. (Germany). Lehrstuhl fuer Stroemungsmechanik.

ON THE ACCURACY AND EFFICIENCY OF CFD METHODS IN REAL GAS HYPERSONICS

D. DRIKAKIS and S. TSANGARIS (National Technical Univ., Athens, Greece.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 15 p (SEE N94-10421 01-02) Apr. 1993

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A study of viscous and inviscid hypersonic flows, using generalized upwind methods, is presented. A new family of hybrid flux splitting methods is examined for hypersonic flows. A hybrid method is constructed by the superposition of the Flux Vector Splitting (FVS) method and second order artificial dissipation in the regions of the strong shock waves. The conservative variables on the cell faces are calculated by an upwind extrapolation scheme third order of accuracy. A second order accurate scheme is used for the discretization of the viscous terms. The solution of the system of equations is succeeded by an implicit unfactored method. In order to reduce the computational time a Local Adaptive Mesh Solution (LAMS) method is proposed. LAMS method combines the mesh sequencing technique and the local solution of the equations. Local solution of either Euler or Navier-Stokes equations is applied in the region of the flow field where numerical disturbances are died out slowly. Validation of the Euler and Navier-Stokes codes is obtained for hypersonic flows around blunt bodies. Real gas effects are introduced via a generalized equation of state. Extension of numerical methods in real gas hypersonics is presented for the hybrid FVS method and a Riemann solver. Author

N94-10463*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

A COMPARISON OF HIGH RESOLUTION UPWIND SOLVERS ON 3-D INVISCID HYPERSONIC FLOWS

M. MANNA (Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese, Belgium.), H. DECONINCK (Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese, Belgium.), C. P. LI, and E. MA *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 14 p (SEE N94-10421 01-02) Apr. 1993

(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

A detailed comparison of numerical results obtained by solving the Euler equations for the inviscid flow over delta wings in reentry configurations is presented. The investigation involves a side-by-side comparison between independently developed upwind Euler solvers at VKI (M3D) and NASA Johnson Space Center (E3D) using identical grids. In both solvers the governing equations are integrated by means of time marching finite volume shock capturing methods, based on a cell centered upwind evaluation of the cell face fluxes and nonlinear limiters. High resolution schemes are obtained via MUSCL characteristic variable extrapolation to ensure total variation diminishing (TVD) properties and therefore monotonic discontinuity capturing. Further comparisons are made with several published results by other authors based on both upwind and central discretizations. The present results contribute in asserting the high resolution upwind TVD schemes as the most reliable numerical technique to handle the strong discontinuities typical of high speed flows. The performances of the two upwind solvers are satisfactory and the numerical results in good agreement. However, the important issue of reaching a grid converged solution for the present complex three-dimensional inviscid flow problems was not achieved. Author (revised)

N94-10464# Avions Marcel Dassault, Saint-Cloud (France).

LOCAL AEROTHERMAL PROBLEMS DURING HERMES RE-ENTRY

A. NAIM, M. MALLET, P. ROSTAND, and J. M. HASHOLDER *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 16 p (SEE N94-10421 01-02) Apr. 1993 In FRENCH Original contains color illustrations

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The objective is to present results obtained with the Navier Stokes code used by Dassault Aviation for aerothermal reentry problems. We will emphasize the strategy employed and only give an outline of the numerical technique developed for each solver involved in the calculation. The method is designed to have a wide range of application. It involved a sequence of calculations using different modules and interfaces. This tool is not only multi-codes but also multi-computers. The preparation of the initial solution sets for computations were performed on our IBM ES 9000/820 with MVS ESA operating system, and most of the computation was done on a NEC SX3 (at NLR in the Nederlands) and on a CRAY YMP (at C.I.R.A. in Italy) with UNIX operating system. We shall present a validation case using the complete sequence, and afterwards a number of critical points of microaerothermodynamics. The validation test case is a Complete Hermes canopy of the 0.0 geometry (shape number 185 in Dassault catalog). A model of this shape was tested in R3CH ONERA wind tunnel yielding experimental results that are used for comparison. For the flight cases we plan to compute: various canopy shapes; a meteorite impact on the Hermes noze cap; and joint between tiles (in first tile position). Author (revised)

N94-10465# Rome Univ. (Italy). Dept. of Mechanics and Aeronautics.

THERMAL AND CHEMICAL NON EQUILIBRIUM HYPERSONIC FLOW COMPUTATIONS

F. GRASSO and V. BELLUCCI *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 11 p (SEE N94-10421 01-02) Apr. 1993

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A two-temperature model was developed for the description of thermal and chemical nonequilibrium viscous hypersonic flows. The model employs a vibrational coupling factor as proposed by Treanor and Marrone, and it uses a model based on a non-preferential removal of vibrational energy. The technique relies on a finite volume approach based on a second order accurate Total Variation Diminishing (TVD) formulation that accounts for thermal and chemical nonequilibrium effects. The stiffness due to the disparity

in time scales is reduced by introducing a precondition matrix that allows a pointwise implicit solution of the source terms. Applications of the model to compute viscous hypersonic flows over a wedge and a cylinder showed that the postshock temperature plays a fundamental role in the achievement of thermal equilibrium and that the boundary layer is the most affected by thermal nonequilibrium. Author (revised)

N94-18417# Middle East Technical Univ., Ankara (Turkey). Dept. of Aeronautical Engineering.
EXPERIMENTAL INVESTIGATION OF FLOW AROUND A MULTIELEMENT AIRFOIL
NAFIZ ALEMDAROGLU *In* AGARD, High-Lift System Aerodynamics 19 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

This paper presents the results of experimental investigations performed around a multielement airfoil and gives detailed information about the flow in and around the flap-well and slat cavity regions. Measurements are made using pitot probes, hotwire anemometer and laser Doppler velocimeter at a Reynolds number of 0.5 and 0.8x10(exp 6). The results obtained show the complex nature of the shear flows investigated and put into evidence the necessity of accurate modeling of these flows by numerical methods. Author (revised)

N94-18419# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany).
CALCULATION OF MAXIMUM AND HIGH LIFT CHARACTERISTICS OF MULTI ELEMENT AEROFOILS
WILLY FRITZ *In* AGARD, High-Lift System Aerodynamics 12 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

The flow field around multi-element aerofoil sections possesses a high degree of complexity. Due to the strong interactions between wakes from the upstream elements and the upper surface boundary layers developing on the downstream elements, there are thick viscous layers present over the upper surface of the trailing edge flap. Large regions of separated flow can be present, even for conditions well below maximum lift. Finally, the flow around the leading edge slat can become locally supersonic, even for low freestream Mach numbers, due to the large suction levels induced in this region. The viscous-inviscid interaction methods, which are most widely in use for the prediction of multi-element aerofoil flows, are computationally very efficient, but unable to describe many of the complex flow features present. A more complete description of the physical phenomena can be achieved only by methods based on a solution of the Reynolds-averaged Navier-Stokes equations, in conjunction with a suitable turbulence model. The generation of a suitable computational grid then becomes a major problem. Within the present work, a method to generate suitable block structured grids around multi-element aerofoils has been developed. The Dornier 2-D block structured Navier-Stokes solver has been extended for grids with arbitrary block structure. After very encouraging results for a two-element high lift system at low angles of attack, in this work the method was applied for realistic two- and three-element high lift systems at high angles of attack. Derived from text

N94-18420# Technische Univ., Berlin (Germany). Inst. fuer Luft- und Raumfahrt.
NAVIER-STOKES COMPUTATIONS OF TURBULENT FLOW AROUND HIGH-LIFT CONFIGURATIONS
P. BARTSCH, W. NITSCHE, and M. BRITSCH *In* AGARD, High-Lift System Aerodynamics 10 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

This paper presents Navier-Stokes calculations of the turbulent flow around two different high-lift configurations, for which experimental data exist. In the calculations, the flow field is considered as of steady-state and two-dimensional. Because of the low Mach numbers, the fluid is treated as incompressible. The solution procedure uses a finite volume method in order to solve the Reynolds-averaged Navier-Stokes equations. The effects of turbulence on the mean flow field are described by the k-epsilon turbulence model. The computational mesh is systematically refined in order to assess numerical solution errors. The results presented in this paper include surface pressure distributions as well as mean velocities and turbulence quantities. If possible, the calculations are compared to experimental data. Author

N94-18421*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EFFICIENT SIMULATION OF INCOMPRESSIBLE VISCOUS FLOW OVER MULTI-ELEMENT AIRFOILS
STUART E. ROGERS, N. LYN WILTBERGER, and DOCHAN KWAK *In* AGARD, High-Lift System Aerodynamics 9 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

The incompressible, viscous, turbulent flow over single and multi-element airfoils is numerically simulated in an efficient manner by solving the incompressible Navier-Stokes equations. The solution algorithm employs the method of pseudo compressibility and utilizes an upwind differencing scheme for the convective fluxes, and an implicit line-relaxation scheme. The motivation for this work includes interest in studying high-lift take-off and landing configurations of various aircraft. In particular, accurate computation of lift and drag at various angles of attack up to stall is desired. Two different turbulence models are tested in computing the flow over an NACA 4412 airfoil; an accurate prediction of stall is obtained. The approach used for multi-element airfoils involves the use of multiple zones of structured grids fitted to each element. Two different approaches are compared; a patched system of grids, and an overlaid Chimera system of grids. Computational results are presented for two-element, three-element, and four-element airfoil configurations. Excellent agreement with experimental surface pressure coefficients is seen. The code converges in less than 200 iterations, requiring on the order of one minute of CPU time on a CRAY YMP per element in the airfoil configuration. Author (revised)

N94-18422*# McDonnell Aircraft Co., Saint Louis, MO.
NAVIER-STOKES CALCULATIONS ON MULTI-ELEMENT AIRFOILS USING A CHIMERA-BASED SOLVER
DONALD W. JASPER, SHREEKANT AGRAWAL, and BRIAN A. ROBINSON *In* AGARD, High-Lift System Aerodynamics 11 p (SEE N94-18415 04-01) Sep. 1993 Sponsored by NASA. Ames Research Center and Cray Research, Inc.
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A study of Navier-Stokes calculations of flows about multielement airfoils using a chimera grid approach is presented. The chimera approach utilizes structured, overlapped grids which allow great flexibility of grid arrangement and simplifies grid generation. Calculations are made for two-, three-, and four-element airfoils, and modeling of the effect of gap distance between elements is demonstrated for a two element case. Solutions are obtained using the thin-layer form of the Reynolds averaged Navier-Stokes equations with turbulence closure provided by the Baldwin-Lomax algebraic model or the Baldwin-Barth one equation model. The Baldwin-Barth turbulence model is shown to provide better agreement with experimental data and to dramatically improve convergence rates for some cases. Recently developed, improved farfield boundary conditions are incorporated into the solver for greater efficiency. Computed results show good comparison with experimental data which include aerodynamic forces, surface pressures, and boundary layer velocity profiles. Author

N94-18423# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
NUMERICAL SOLUTION OF THE NAVIER-STOKES EQUATIONS FOR HIGH-LIFT CONFIGURATIONS ON STRUCTURED COMPOSITE GRIDS
T. E. NELSON, D. W. ZINGG, and G. W. JOHNSTON *In* AGARD, High-Lift System Aerodynamics 14 p (SEE N94-18415 04-01) Sep. 1993
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A numerical method is presented for the solution of the compressible Reynolds-averaged, thin-layer Navier-Stokes equations on structured composite grids as applied to high-lift configurations. The method is an adaptation of an implicit approximate factorization algorithm for block structured composite grids. Interfaces between blocks are treated by overlapping the grids and taking one layer of points from neighboring blocks. Turbulence is treated using the Baldwin-Barth one-equation turbulence model. High-lift applications presented for comparison with wind tunnel data include: a NACA 4412 airfoil with NACA 4415 flap, a GA(W)-1 airfoil with a 29 percent chord flap at 30 degree flap angle and two gap settings, and a GA(W)-1 airfoil

with 15 percent chord slat and 29 percent chord flap. Good agreement with experimental data is obtained for cases with fully attached flow or small regions of separated flow. For cases with extensive regions of flow separation, the thickness and extent of the separated regions are underpredicted. Author

N94-18424*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

HIGH REYNOLDS NUMBER CONFIGURATION DEVELOPMENT OF A HIGH-LIFT AIRFOIL

WALTER O. VALAREZO (Douglas Aircraft Co., Inc., Long Beach, CA.), CHET J. DOMINIK (Douglas Aircraft Co., Inc., Long Beach, CA.), ROBERT J. MCGHEE, and WESLEY L. GOODMAN *In* AGARD, High-Lift System Aerodynamics 8 p (SEE N94-18415 04-01) Sep. 1993

(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

An experimental program has been conducted to assess performance of a transport multielement airfoil at flight Reynolds numbers. The studies were performed at chord Reynolds numbers as high as 16 million in the NASA Langley Low Turbulence Pressure Tunnel. Sidewall boundary-layer control to enforce flow two dimensionality was provided via an endplate suction system. The basic airfoil was an 11.55 percent thick supercritical airfoil representative of the stall critical station of a new-generation transport aircraft wing. The multielement airfoil was configured as a three-element airfoil with slat and flap chord ratios of 14.48 percent and 30 percent respectively. Testing focused on the development of landing configurations with high maximum lift capability and the assessment of Reynolds and Mach number effects. Also assessed were high-lift performance effects due to devices such as drooped spoilers and trailing-edge wedges. The present experimental studies revealed significant effects on high-lift airfoil performance due to Reynolds and Mach number variations and favorable lift increments at approach angles of attack due to the use of drooped spoilers or trailing-edge wedges. However, no substantial improvements in maximum lift capability were identified. A recently developed high performance single-segment flap was also tested and results indicated considerable improvements in lift and drag performance over existing airfoils. Additionally, it was found that this new flap shape at its optimum rigging was less sensitive to Reynolds number variations than previous designs. Author

N94-18425# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

A VISCOUS-INVISCID SOLVER FOR HIGH-LIFT INCOMPRESSIBLE FLOWS OVER MULTI-ELEMENT AIRFOILS AT DEEP SEPARATION CONDITIONS [UNE METHODE D'INTERACTION VISQUEUX NON-VISQUEUX POUR ECOULEMENTS INCOMPRESSIBLES HYPERSUSTENTES SUR PROFILS MULTI-CORPS EN REGIME DE DECOLLEMENT PROFOND]

J. C. LEBALLEUR and M. NERON *In* AGARD, High-Lift System Aerodynamics 12 p (SEE N94-18415 04-01) Sep. 1993 In FRENCH

(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

A viscous-inviscid interaction numerical method for incompressible flows over multi-element airfoils, which is an extension of the numerical method previously suggested for compressible attached or separated or even stalled flows over airfoils, is presented. The robust algorithms of the method are capable now to converge well for attached flows or massively separated flows, such as induced by slope discontinuities of airfoils or slats, or such as induced by stall. The viscous-inviscid approach introduces a self-adaptative viscous grid in both normal and streamwise directions along the displacement surfaces, with everywhere a streamwise grid-resolution of the same order as the separating boundary layer thicknesses, even at slat apexes, which is believed to eliminate any aleatory effect of numerical viscosity. The method is validated with respect to ONERA experiments, on the three-element RA16SC1 high-lift device, with the severe AMD slat-geometry. A realistic non-uniqueness of the separated flow solutions has been exhibited by the calculation method. A satisfactory agreement between theory and experiment is obtained, with the suggested 2-equation turbulence model. Author (revised)

N94-18426# National Aerospace Lab., Amsterdam (Netherlands).

HIGH-LIFT SYSTEM ANALYSIS METHOD USING UNSTRUCTURED MESHES

K. DECOCK *In* AGARD, High-Lift System Aerodynamics 20 p (SEE N94-18415 04-01) Sep. 1993

(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

A 2D high-lift configuration analysis method is described. The flow model used is based on the Euler equations, discretized on unstructured meshes. The generation of the unstructured meshes is based on the principle of successive grid adaptation with respect to the geometry. This approach makes later extension towards fully integrated grid adaptation with respect to the solution straightforward. The main characteristics of the Euler solver are upwind flux-difference splitting of the convective part of the Euler equations (second-order accurate discretization in space) and four stage Runge Kutta local time stepping. Results obtained with this analysis method are shown for the NACA0012 airfoil and three-element airfoils. Conclusions are drawn. Author

N94-18427# Manchester Coll. of Science and Technology (England). Dept. of Mechanical Engineering.

PREDICTION OF THE HIGH-LIFT PERFORMANCE OF MULTI-ELEMENT AEROFOILS USING AN UNSTRUCTURED NAVIER-STOKES SOLVER

LESLIE J. JOHNSTON and LUCA STOLCIS *In* AGARD, High-Lift System Aerodynamics 18 p (SEE N94-18415 04-01) Sep. 1993

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(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

A detailed description is presented of a computational method to predict the aerodynamic performance of mechanical high-lift systems. The Reynolds-averaged Navier-Stokes equations applicable to compressible, two-dimensional mean flow are solved using a cell-centered, finite-volume spatial discretization and an explicit multi-stage to time march to steady-state solutions. The governing mean-flow equations are solved in conjunction with a two-equation, high-Reynolds number k-epsilon turbulence model, this level of turbulence model sophistication being considered as the minimum required to enable an adequate resolution of the complex flow physics. The geometric complexity associated with practical multi-element airfoil configurations is addressed by adopting unconstructed computational grids. Results for the RAE 2822 transonic single-airfoil section are presented, comparing two near-wall treatments for the turbulence-transport equations. Thereafter, a detailed evaluation is presented of the predictive capability of the method, in its current form, by comparison with experimental data for the low-speed, high-lift NLR 7301 airfoil/trailing-edge flap configuration. Results are also presented for the SKF 1.1 airfoil/manoeuver flap configuration over a range of transonic flow conditions, from fully-subcritical flow to supercritical flow with shock-induced separation. The level of agreement between predictions and experiment is encouraging for the cases considered. However, it is concluded that improved modeling of the complex flow physics is required, with the lack of response of the current k-epsilon turbulence model to streamline curvature being a significant limitation on quantitative accuracy around maximum lift conditions. Similarly, procedures to automatically adapt the computational grid to the flow solution would improve predictions over the extended range of conditions associated with the practical operation of a mechanical high-lift system. Author (revised)

N94-18428# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. for Design Aerodynamics.

NUMERICAL CALCULATIONS OF HIGH LIFT FLOWS USING STRUCTURED AND UNSTRUCTURED METHODS

R. BAILEY, J. M. A. LONGO, R. RADESPIEL, A. RONZHEIMER, A. DEMIER, N. KROLL, and C.-C. ROSSOW *In* AGARD, High-Lift System Aerodynamics 13 p (SEE N94-18415 04-01) Sep. 1993

(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

At the DLR Institute for Design Aerodynamics current research in the area of high lift aerodynamics is directed towards the development of a computational analysis capability for high lift systems. The Navier-Stokes equations are solved with a multigrid method based on central spatial differencing and Runge-Kutta time stepping. Two particular problems are addressed in this paper. The first concerns the calculation of maximum lift for a single airfoil and a clean wing configuration. The accuracy of the basic

structured flow solver is investigated by comparing the results with experimental data for two test problems and several flow conditions. Emphasis is placed on the sensitivity of the computed solution associated with turbulence modeling. The second aspect dealt with in the present paper concerns the extension of the numerical method to multi-element airfoils. Both, the block-structured and the unstructured grid approach are investigated in order to explore their specific merits and limitations. Detailed comparisons of the structured and unstructured approach are presented for low Reynolds number laminar viscous flows around a single airfoil, and for the inviscid flow around a multi-element airfoil. Author

N94-18429# Grumman Aerospace Corp., Bethpage, NY.
NAVIER-STOKES SIMULATION OF FLOW FIELD AROUND A BLOWN-FLAP HIGH-LIFT SYSTEM
R. CHOW, K. CHU, and G. CARPENTER *In* AGARD, High-Lift System Aerodynamics 10 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

Solution of the Reynolds averaged Navier-Stokes equations is obtained to simulate the flow field around a 13 percent thickness supercritical airfoil slat/blown-flap high-lift system. A stacked-C mesh topology is used in conjunction with the slat and the flap trailing edge streamlines and adapted to accurately locate the strong viscous flow regions. A previously modified PARC2D implicit ADI solver is employed whereby the multiply connected boundary value problem can be treated with a single computation zone. A modeled injection boundary condition was demonstrated to connect transient flap wake vortices downstream of the computational domain. The converged surface pressures and the values of the lift coefficient are compared with the wind tunnel data at M(infinity) = 0.17, Re = 3.4 M for momentum injection coefficients of C(mu) = 0.01 and C(mu) = 0.04, respectively. Author (revised)

N94-18430# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THE GARTEUR HIGH LIFT RESEARCH PROGRAMME
J. J. THIBERT *In* AGARD, High-Lift System Aerodynamics 21 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

An extensive European wind tunnel research program on high lift systems has been carried out in the past few years within the framework of a GARTEUR Action Group. To provide a relevant and realistic case, permission was given by British Aerospace to use a section from the A-310 wing from which a 2D airfoil could be derived. A Deutsche Airbus 3D half model of the A-310 aircraft has been used for the 3D test and an airfoil representative of the 59 percent span section has been used for the 2D test. The wind tunnel test program carried out in the major European low speed wind tunnels (ONERA F1 in France, NLR HST and LST in Netherlands, RAE 5 m in UK) was complemented by a full scale flight test supported by Airbus Industries. A wide range of Reynolds numbers and Mach numbers has been covered by the test and a very comprehensive, well integrated and accurate body of data has been generated by this research program. After presenting GARTEUR the paper deals with the Reynolds number and the Mach number effects as well as the correlations between 2D and 3D data and between wind tunnel and flight test results. Author

N94-18433# Boeing Commercial Airplane Co., Seattle, WA.
VISCOUS PHENOMENA AFFECTING HIGH-LIFT SYSTEMS AND SUGGESTIONS FOR FUTURE CFD DEVELOPMENT
P. T. MEREDITH *In* AGARD, High-Lift System Aerodynamics 8 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

This paper describes a number of viscous phenomena which affect the aerodynamic performance of high-lift systems typical of commercial jet transports. The nature of these phenomena suggest a course of action regarding the continuing development of computational fluid dynamics (CFD): in addition to the ongoing work of grid generation and algorithm development, increased attention to fundamental fluid mechanics is called for. Author

N94-18434# Defence Research Agency, Farnborough, Hampshire (England).
A STUDY OF THE USE OF HALF-MODELS IN HIGH-LIFT WIND-TUNNEL TESTING
P. B. EARNSHAW, A. R. GREEN, B. C. HARDY, and A. H. JELLY *In* AGARD, High-Lift System Aerodynamics 9 p (SEE N94-18415 04-01) Sep. 1993
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An experimental investigation into the use of half-model testing techniques specifically aimed at high-lift testing has been carried out in the 5 Metre Pressurized Wind Tunnel at the DRA, Farnborough. The aim of the program was to provide an assessment of the extent to which the measured characteristics of a high-lift model might be compromised by, in particular, the existence of a boundary layer on the reflection plane and how any penalties might be minimized. The results suggest that, provided care is taken with experimental technique, good agreement is possible on stall incidence as well as the absolute values of lift, drag and pitching moment. Author

N94-18435*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
IN-FLIGHT PRESSURE DISTRIBUTIONS AND SKIN-FRICTION MEASUREMENTS ON A SUBSONIC TRANSPORT HIGH-LIFT WING SECTION
LONG P. YIP, PAUL M. H. W. VIJGEN (High Technology Corp., Hampton, VA.), JAY D. HARDIN (Lockheed Engineering and Sciences Co., Hampton, VA.), and C. P. VANDAM (California Univ., Davis.) *In* AGARD, High-Lift System Aerodynamics 19 p (SEE N94-18415 04-01) Sep. 1993
(Contract(s)/Grant(s): NAS1-19299; NAS1-19000; NCC1-163)
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

Flight experiments are being conducted as part of a multiphased subsonic transport high-lift research program for correlation with wind-tunnel and computational results. The NASA Langley Transport Systems Research Vehicle (B737-100 aircraft) is used to obtain in-flight flow characteristics at full-scale Reynolds numbers to contribute to the understanding of 3-D high-lift, multi-element flows including attachment-line transition and relaminarization, confluent boundary-layer development, and flow separation characteristics. Flight test results of pressure distributions and skin friction measurements were obtained for a full-chord wing section including the slat, main-wing, and triple-slotted, Fowler flap elements. Test conditions included a range of flap deflections, chord Reynolds numbers (10 to 21 million), and Mach numbers (0.16 to 0.40). Pressure distributions were obtained at 144 chordwise locations of a wing section (53-percent wing span) using thin pressure belts over the slat, main-wing, and flap elements. Flow characteristics observed in the chordwise pressure distributions included leading-edge regions of high subsonic flows, leading-edge attachment-line locations, slat and main-wing cove-flow separation and reattachment, and trailing-edge flap separation. In addition to the pressure distributions, limited skin-friction measurements were made using Preston-tube probes. Preston-tube measurements on the slat upper surface suggested relaminarization of the turbulent flow introduced by the pressure belt on the slat leading-edge surface when the slat attachment line was laminar. Computational analysis of the in-flight pressure measurements using two-dimensional, viscous multielement methods modified with simple-sweep theory showed reasonable agreement. However, overprediction of the pressures on the flap elements suggests a need for better detailed measurements and improved modeling of confluent boundary layers as well as inclusion of three-dimensional viscous effects in the analysis. Author

N94-18437# Institut fuer Theoretische Stroemungsmechanik, Goettingen (Germany).
A FAST COMPUTING METHOD FOR THE FLOW OVER HIGH-LIFT WINGS
K. JACOB *In* AGARD, High-Lift System Aerodynamics 12 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

A quasi 3-dimensional method for analyzing the viscous steady subsonic flow over wings with flaps for high lift is briefly presented. The total iterative procedure combines a 3-dimensional inviscid lifting surface theory with a 2-dimensional surface-singularity method for analyzing multi-element airfoils in a curved basic flow field. This method also includes boundary layer calculations and a

model for rear separation. Also, small compressibility effects are accounted for by simple corrections, and ground effects are included by means of the reflected image technique. First attempts to validate the method by a few theory-experiment comparisons are reported. The results are encouraging but more experimental data are needed for a thorough validation. The computing time requirements of the method are modest. Author

N94-18438# California State Univ., Long Beach, CA. Dept. of Aerospace Engineering.
CALCULATION OF MULTIELEMENT AIRFOILS AND WINGS AT HIGH LIFT
TUNCER CEBECI *In* AGARD, High-Lift System Aerodynamics 15 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

A calculation method based on an interactive boundary-layer approach to multi-element airfoils and wings is described. For two-dimensional flows, the method is applied to three types of airfoil configurations with and without flap wells in order to demonstrate its applicability and accuracy to general high-lift configurations. This method, extensively tested for single airfoils as a function of shape, angle of attack, and Reynolds number, is shown here to apply equally well to multi-element airfoils. The calculation method is also applied to a wing and wing/flap configuration in order to demonstrate its promise for addressing three-dimensional flows. Preliminary results indicate that with further development, the method, as for multi-element airfoils, will also become a practical, accurate and efficient tool for multi-element wings. Author

N94-18439# Politecnico di Milano, Milan (Italy). Dipt. di Ingegneria Aerospaziale.
WAKE STRUCTURE AND AERODYNAMIC BEHAVIOR OF HIGH LIFT AIRCRAFT CONFIGURATIONS DURING UNSTEADY MANEUVERS IN GROUND EFFECT
A. BARON and M. BOFFADOSSI *In* AGARD, High-Lift System Aerodynamics 15 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

A nonlinear unsteady vortex lattice scheme is used and flight dynamics equations are solved in order to predict the structure of the wakes and the instantaneous distribution of the aerodynamic loads on high-lift aircraft configurations, during general unsteady take-off maneuvers in ground effect. The numerical scheme here presented can treat an arbitrary number of mutually interfering lifting and moving control surfaces having arbitrary planform and camber. Wakes can be released in the flowfield from any of the sharp edges of the lifting surfaces, depending on their planform, aspect ratio and angle of attack, while the effects of the fuselage are ignored in the present formulation. Turbulent diffusion of the cores of the Rankine vortex filaments is regarded as a preeminent factor in a correct simulation of the development of unsteady interfering wakes. A vortex core diffusion model is used capable to deal even with the severe roll-up of the mutually interfering wakes developing close and impinging on the ground. Typical applications of the unsteady vortex lattice scheme are presented, aimed at illustrating the capabilities of the code. Author

N94-18440# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
VISCOUS-INVISCID CALCULATION OF HIGH-LIFT SEPARATED COMPRESSIBLE FLOWS OVER AIRFOILS AND WINGS [CALCUL PAR INTERACTION VISQUEUX NON-VISQUEUX DES ECOULEMENTS COMPRESSIBLES FORTEMENT DECOLLES AUX GRANDES PORTANCES SUR PROFILS D'AILES ET VOILURES]
J. C. LEBALLEUR *In* AGARD, High-Lift System Aerodynamics 18 p (SEE N94-18415 04-01) Sep. 1993 In FRENCH Sponsored by Ministry of Defence
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

The viscous-inviscid interaction transonic numerical method previously defined by the author for computing attached or separated flows over airfoils, including the deeply stalled flows, is extended into a new three-dimensional method for strongly separated flows over wings at high-lift and compressible speeds. The numerical nonlinearly implicit boundary layer technique (direct/inverse), the turbulent models, the grid generation and grid-adaption, the coupling and wake-equilibration algorithms, the inviscid full-potential schemes, are extended in three dimension, with approximation on the viscous equations (2.75D-local). New theoretical results are given on the singularities and characteristic cones of the fully three-dimensional boundary layer in inverse mode. A new 'Massive-separation 2.75D' extension of the 'Semi-inverse' algorithm of Le Balleur for coupling is given and detailed, together with its stability theory. Results are shown for 2D-stall, and for 3D separated flows over rectangular or swept wings, with satisfactory agreement between theory and experiment. A self-adaptation technique of the grid to the viscous effects is displayed. The results demonstrate that the viscous-inviscid interaction methods give a full access to the calculation of three-dimensional separation. Author (revised)

N94-28021# Southampton Univ. (England). Dept. of Aeronautics and Astronautics.
COMPARISON OF THE INTERACTIONS OF TWO AND THREE DIMENSIONAL TRANSVERSE JETS WITH A HYPERSONIC FREE STREAM
H. E. G. POWRIE, G. J. BALL, and R. A. EAST *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 8 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by Defence Research Agency
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

The interaction between a three dimensional (circular) sonic jet and a Mach 6.69 cross flow on a flat plate has been investigated experimentally. The results are compared with data from a two dimensional (slot) sonic jet in the same flow. In both cases the undisturbed flow on the plate is laminar. Heat transfer and oil flow visualization have been used to identify separation and reattachment within the flow field which, for the case of circular injection, has revealed a number of vortex cells in the region ahead of the jet. For the two dimensional interaction there is only evidence of one vortex pair in this region; however, a complex flow downstream of the slot jet has been observed. The influence of injectant gas type on the two dimensional interaction flow field is limited to a weak molecular weight dependence implied by separation length data. In contrast, for three dimensional injection, jet gas composition is found to have a marked effect on the size of the interaction flow field, as well as influencing surface heat transfer rate in the vicinity of the injector. Author (revised)

N94-28022# Institut Franco-Allemand de Recherches, Saint-Louis (France).
EXPERIMENTS ON INTERACTION FORCE OF JETS IN HYPERVELOCITY CROSS-FLOW IN A SHOCK TUNNEL
K. W. NAUMANN, H. ENDE, G. MATHIEU, and A. GEORGE *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 12 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A03/MF A04

This paper discusses experiments on side-jet control efficiency in the hypervelocity flow of a shock tunnel. The parameters of the test flow represent the Mach number, Reynolds number, velocity, and density of tropospheric hypervelocity flight. The experiments are carried out with a model, which is equipped with pyrotechnical charges, a settling chamber, laterally blowing jets, and a set of small accelerometers. The pyrotechnically supplied side-jets also are roughly adequate to those used in sound vehicles. Extensive jet gas diagnostics yield the parameters of the gas and the nozzle flow. The accelerometers incorporated in the model allow direct millisecond aerodynamic force measurement. To provide free-flight during the testing time, a fast-acting mounting support releases the model and grips it again when the test flow has passed the model. Using measured acceleration and Pitot pressure histories allows direct straightforward time-dependent evaluation of the aerodynamic coefficients. The procedure is insensitive to disturbances in the starting phase of the flow or moderate flow variations. The results quantify the force, which is produced by interaction of side-jets and ambient flow, and acts on the surface of the model. At the tropospheric hypervelocity conditions of our test, the interaction force on a flat plate substantially increases jet thrust. Moreover, the results quantify the time necessary to establish quasistationary flow for the actual test conditions. Author (revised)

N94-28027# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft Div.
EFFECTS, LIMITS, AND LIMITATIONS OF SPANWISE BLOWING
W. H. STAUDACHER *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04
Concentrated spanwise blowing over wings is a technique using mainly the secondary (= nonreactive) effects of a jet in crossflow, with the primary intention to generate and/or stabilize and control separated rolled-up leading edge vortex systems. This means an indirect application of a crossflow jet via triggering another crossflow phenomenon, the L.E. vortex. Based on the results of extensive experimental research, the merits and shortcomings of this technique are overviewed concerning aerodynamic performances, and stability and control aspects. The limits of aerodynamics efficiency are established on an empirical/theoretical basis and compared to experimental results. There is found a definite upper and lower boundary. The author's view is given concerning the practical (non-) applicability of this simple technique and the reasons for missing examples in operational aircraft are discussed via comparison to competitive approaches. Author

N94-28029# Stanford Univ., CA.
THEORETICAL AND EXPERIMENTAL INVESTIGATION OF A DELTA WING WITH TURBULENT LEADING-EDGE JETS
K. J. CRAIG, L. ROBERTS, D. I. GREENWELL (Bath Univ., England.), and N. J. WOOD (Bath Univ., England.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 13 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A03/MF A04
Control of the separated flow over a delta wing using Tangential Leading-Edge Blowing has been investigated experimentally and computationally. Tangential Leading-Edge Blowing describes the injection of momentum into the cross flow plane of the wing by thin Coanda wall jets located at the point of cross flow separation. The concept is shown to be capable of generating significant asymmetry in the vortical flowfield, and hence a lateral control capability, up to very high angles of attack. The primary effects of jet blowing have been modeled using a Navier-Stokes computation with an algebraic turbulence model. Author

N94-28031# Aerospatiale, Verrieres-L-Buisson (France).
NUMERICAL ASSESSMENT OF AERODYNAMIC INTERACTIONS ON MISSILES WITH TRANSVERSE JETS CONTROL
M. DORMIEUX and R. MARSAA-POEY *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 11 p (SEE N94-28003 07-34) Nov. 1993 Sponsored in part by Ministry of Defence
(AGARD-CP-534) Copyright Avail: CASI HC A03/MF A04
This paper deals with numerical studies made at AEROSPATIALE-MISSILES about aerodynamic interactions due to the use of pyrotechnical lateral force control. Calculations were performed in order to predict lateral jets interactions on two kinds of missiles: subsonic antitank and supersonic antimissile. In the subsonic case, Euler and Navier-Stokes calculations were compared on a missile body test case. Then, Euler code was applied to an antitank missile configuration, and missile spinning effects were assessed. In the supersonic case, jet stagnation temperature and jet species effects were studied on a surface-to-air missile. Author

N94-28039# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Direction de l'Aerodynamique.
EXPERIMENTAL STUDY ON THE INTERACTIONS BETWEEN A TRANSVERSE HEATED SUPERSONIC JET AND AN EXTERNAL SUPERSONIC FLOW [ETUDE EXPERIMENTALE SUR LES INTERACTIONS ENTRE UN JET SUPERSONIQUE CHAUFFE TRANSVERSAL ET UN ECOULEMENT SUPERSONIQUE EXTERNE]
R. GAILLARD, P. GEFFROY, L. JACQUIN, and G. LOSFELD *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 12 p (SEE N94-28003 07-34) Nov. 1993 In FRENCH
(AGARD-CP-534) Copyright Avail: CASI HC A03/MF A04
This paper presents the techniques implemented as well as a collection of the results obtained during an experimentation leading to the S5 wind tunnel of ONERA in the case of a transverse jet of Mach number equal to 2, strongly heated, emerging in a perpendicular flow of the same Mach number. The flow is qualified by means of a miniature 5 hole probe, by thermocouples and tridirectional laser velocimetry. The effects of the temperature on the average and turbulent properties of the jet are discussed. Clear strioscopies are also presented. They highlight the strongly nonstationary nature of this interaction. Transl. by FLS

N94-28040# City Univ., London (England). Dept. of Mechanical Engineering and Aeronautics.
INCLINED AIR-JETS USED AS VORTEX GENERATORS TO SUPPRESS SHOCK-INDUCED SEPARATION
H. H. PEARCEY, K. RAO, and D. M. SYKES *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by British Aerospace Defence Ltd.
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04
Experiments have been performed to assess the effectiveness of air-jet vortex generators as alternative to vanes in suppressing shock-induced separation. It is shown that a single jet inclined to the plane of the surface and skewed to the direction of the undisturbed stream produces a single strong vortex and can therefore be treated as the equivalent of a single vane. It follows that jets can be installed in arrays to correspond to arrays of vane vortex generators. A spanwise array of jets is shown to produce closely similar results to an array of co-rotating vane vortex generators of the type that has now been used in very many applications to suppress the effects of shock-induced separation. Air-jet vortex generators should therefore be equally effective in practice and may have significant inherent advantages for many applications. The vortex generators were effective for shock upstream Mach numbers up to and beyond 1.6. The maximum effectiveness occurred close to the generators but they remained reasonably effective for a range of shock positions of up to 50% chord. Some initial pointers are given on the influence of certain design parameters and on what considerations would apply in tailoring the jets to specific applications. Author

N94-34612# Dassault Aviation, Saint-Cloud (France).
HIGH INCIDENCE FLOW ANALYSIS OVER THE RAFALE A [ANALYSE THEORIQUE DE L'ECOULEMENT AUTOUR D'UN RAFALE A A GRANDE INCIDENCE]
JEAN-DENIS MARION *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 7 p (SEE N94-34605 10-05) Mar. 1994 In FRENCH
(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03
A good high angle of attack (AoA) behavior is a requisite for any new combat aircraft. In order to gain a better knowledge of the flow at high AoA, computation over the 'RAFALE A' has been conducted. The aircraft is in a full nose down controls configuration: low speed, low altitude, high AoA, and large control surfaces deflection. Moreover, slideslip is considered so as to assess the lateral behavior of the aircraft in this high AoA regime. The computational domain around the complete aircraft is discretized into an unstructured mesh and the flow is computed with a 3D inviscid (Euler) approach in finite elements. Aerodynamic coefficients have been analyzed together with the topology of the flow in these high AoA configurations. Results have been found to yield a promising agreement concerning the flow features (loss of weathercock stability at high AoA) although absolute values of coefficients are still beyond reach of this basic methodology. In an attempt to get insight into nonsymmetric flow as it can be

found experimentally at high AoA, a modification of the boundary conditions which create a source of vorticity has been implemented. This leads to the existence of large amplitude side forces agreeing with experiments. Author (revised)

N95-14103# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SCALE EFFECTS ON AIRCRAFT AND WEAPON AERODYNAMICS [LES EFFETS D'ECHELLE ET L'AERODYNAMIQUE DES AERONEFS ET DES SYSTEMES D'ARMES]
A. BARRY HAINES (Aircraft Research Association Ltd., Bedford, England.) and A. D. YOUNG Jul. 1994 247 p
(AGARD-AG-323; ISBN-92-835-0754-1) Copyright Avail: CASI HC A11/MF A03

The present state of knowledge on scale effects at high lift and low speeds, at transonic speeds, and on aircraft drag are presented. In addition, scale effects in various important specific scale-sensitive areas such as forebody vortex flows, the flow in and near open cavities, the flow into an air intake, the flow over propellers, and on ice accretion simulation testing are discussed. The emphasis is on scale effects that have been observed in flight-tunnel comparisons for specific aircraft. It is concluded that much has been learned about scale effects; however, precise prediction can still be difficult. Twenty recommendations for further research are mentioned. This AGARDograph has been produced at the request of the Fluid Dynamics Panel of AGARD. Author

N95-14197# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
QUALITY ASSESSMENT FOR WIND TUNNEL TESTING [L'APPRECIATION DE LA QUALITE POUR LES ESSAIS EN SOUFFLERIE]
Jul. 1994 92 p
(AGARD-AR-304; ISBN-92-835-0753-3) Copyright Avail: CASI HC A05/MF A01

The wind tunnel continues to be the main instrument for providing experimental aerodynamic data to the aerospace industry and the aerodynamic researcher for the purpose of load and performance evaluation of theoretical results. In both cases, it is imperative that the user has confidence in the quality of the results, which means that he must have information of what accuracy to attach to the data. This report describes a practical approach for assessing the uncertainty of experimental measurements. Although it concentrates on aerodynamic references data, the approach presented can be used to report data and associated uncertainties for any other condition. The methodology described is designed to facilitate communications and to encourage professional and practical analyses of complex problems. The most recent accepted technical concepts have been included in the methodology. This report presents the results of a study by Working Group 15 of the AGARD Fluid Dynamics Panel. Author

N95-14264# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
COMPUTATIONAL AERODYNAMICS BASED ON THE EULER EQUATIONS [L'AERODYNAMIQUE NUMERIQUE A PARTIR DES EQUATIONS D'EULER]
J. W. SLOOFF, ed. (National Aerospace Lab., Amsterdam, Netherlands.) and W. SCHMIDT, ed. (Deutsche Aerospace A.G., Munich, Germany.) Sep. 1994 250 p Original contains color illustrations
(AGARD-AG-325; ISBN-92-836-1005-9) Copyright Avail: CASI HC A11/MF A03

A survey of the state of the art of Computational Aerodynamics based on the Euler Equations is presented. For the major Euler Codes that are currently in use in the NATO countries, numerical schemes, algorithms, grid generation, physical and numerical aspects, as well as a wide range of applications are included. Background material required for understanding the physics modelled by the Euler Equations is also presented. Areas of application concentrate on numerical simulation of external flows about aerospace vehicles. Internal flows and turbomachinery applications are not extensively treated but touched upon where considered appropriate. Author

N95-14445# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
MISSILE AERODYNAMICS [L'AERODYNAMIQUE DES MISSILES]
Jun. 1994 341 p Special course held in Rhode-Saint-Genese, Belgium, 6-10 Jun. 1994 and in Ankara, Turkey, 13-17 Jun. 1994; sponsored by AGARD and VKI
(AGARD-R-804; ISBN-92-835-0752-5) Copyright Avail: CASI HC A15/MF A03

Lecture notes for the AGARD Fluid Dynamics Panel (FDP) Special Course on 'Missile Aerodynamics' have been assembled in this report. The aim and scope of this course was to present the current state of the art on specific topics of tactical missile aerodynamics. Specifically, topics and methods covered include: Aeromechanical Design of Modern Missiles, Semi-empirical Predictive Tools, Lateral Jet Control, High Angle of Attack Aerodynamics, Analysis and Modelling of Missile Infrared Radiation, Navier-Stokes Computations for Complete Missile Configurations, and Navier-Stokes and Euler Computations for Supersonic Air Intakes. The material assembled in this report was prepared under the combined sponsorship of the AGARD Fluid Dynamics Panel, the Consultant and Exchange Program of AGARD, and the von Karman Institute (VKI) for Fluid Dynamics. For individual titles, see N95-14446 through N95-14452.

N95-14446# Deutsche Aerospace A.G., Munich (Germany). Missile Systems Div.
AEROMECHANICAL DESIGN OF MODERN MISSILES
P. HENNIG and P. G. LACAU *In* AGARD, Missile Aerodynamics 76 p (SEE N95-14445 03-02) Jun. 1994
(AGARD-R-804) Copyright Avail: CASI HC A05/MF A03

The changes in the political and strategic situation in the world, especially in Europe, result in new kinds of military scenarios and in different approaches to well-known scenarios. In combination with technological advances and with new mathematical and physical solutions for system component design and for improvements in system performance this leads to a request for advanced and new types of missiles with corresponding design goals and criteria. From such more general demands associated with the overall system design new requirements for the aerodynamical and aeromechanical design goals can be derived in correspondence. Advanced experimental and theoretical tools support the project aerodynamicist in coping with these new problems. Examples for the demands for new missile types and for the new system requirements are given. The most important aeromechanical work packages in the design procedure of modern missiles are identified and methods to get solutions sufficient for qualitative answers in early project phases are presented. Author

N95-14447# Naval Surface Warfare Center, Dahlgren, VA. Weapons Systems Dept.
ENGINEERING CODES FOR AEROPREDICTION: STATE-OF-THE-ART AND NEW METHODS
FRANK G. MOORE *In* AGARD, Missile Aerodynamics 82 p (SEE N95-14445 03-02) Jun. 1994
(AGARD-R-804) Copyright Avail: CASI HC A05/MF A03

This paper discusses the pros and cons of numerical, semiempirical, and empirical aeroprediction codes. It then summarizes many of the more popular approximate analytical methods used in state-of-the-art (SOTA) semiempirical aeroprediction codes. It also summarizes some recent new nonlinear semiempirical methods that allow more accurate calculation of static aerodynamics on complete missile configurations to higher angles of attack. Results of static aerodynamic calculations on complete missile configurations compared to wind tunnel data are shown for several configurations at various flight conditions. Calculations show the new nonlinear methods being far superior to some of the former linear technology when used at angles of attack greater than about 15 degrees. Author

N95-14450# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
HIGH ANGLE OF ATTACK AERODYNAMICS
P. CHAMPIGNY *In* AGARD, Missile Aerodynamics 19 p (SEE N95-14445 03-02) Jun. 1994
(AGARD-R-804) Copyright Avail: CASI HC A03/MF A03

The demand for continually increased performance of missiles and aircraft leads to considering flight at very high angles of attack where control is very difficult. This is mainly due to the shedding of asymmetric vortices from the forebody, producing side forces even at zero sideslip. The purpose of this paper is not to make a review of missile aerodynamics at high angle of attack, but to focus on an understanding of the phenomena which give rise to asymmetric vortices, from an experimental as well as a theoretical point of view. Author

N95-14451# Army Research Lab., Aberdeen Proving Ground, MD. Propulsion and Flight Div.
NAVIER-STOKES PREDICTIONS OF MISSILE AERODYNAMICS
PAUL WEINACHT and JUBARAJ SAHU *In* AGARD, Missile Aerodynamics 48 p (SEE N95-14445 03-02) Jun. 1994
(AGARD-R-804) Copyright Avail: CASI HC A03/MF A03

This paper discusses the application of Navier-Stokes computational methods to the prediction of the aerodynamics of missile configurations. The governing equations, turbulence models, and numerical approaches used to solve these equations are briefly described. The paper focuses mainly on aerodynamic coefficient prediction. Static and dynamic aerodynamic derivative prediction methods and applications are presented for axisymmetric and finned bodies and comparisons are made with experimental data. Results of validation studies are also presented for the purpose of demonstrating the accuracy as well as potential shortcomings of these techniques. The paper also discusses the application of Navier-Stokes methods in the prediction of base flow. Application of these techniques to unpowered, base bleed, and powered configurations is shown. Author

N95-14452# Aerospatiale, Verrieres-L-Buisson (France).
COMPUTATION OF SUPERSONIC AIR-INTAKES
R. G. LACAU, P. GARNERO, and F. GAIBLE *In* AGARD, Missile Aerodynamics 21 p (SEE N95-14445 03-02) Jun. 1994
(AGARD-R-804) Copyright Avail: CASI HC A03/MF A03

The aim of this paper is to present how some CFD tools can be used to compute external and internal flowfields involved in the design of supersonic air-intakes. These tools help the designer to better understand flow phenomena, to determine favorable intake locations, and to predict air-intake performances such as pressure recovery and mass flow ratio. As supersonic intakes are mainly used on ramjet missiles, we limit this paper to ramjet air-intakes. After a brief overview of the existing types of air-intakes, we describe the way their performances are quantified. Then we present the CFD tools used to evaluate air-intake characteristics. Finally, selected applications of these tools demonstrate how a comprehensive study of air-intake may be achieved through CFD. Both external and internal flowfield computations are presented, which allows predictions of air-intake performances. Derived from text

N95-14894# Pennsylvania State Univ., University Park, PA. Dept. of Aerospace Engineering.
WAKE TURBULENCE
BARNES W. MCCORMICK *In* AGARD, Flight in an Adverse Environment 15 p (SEE N95-14893 03-03) Nov. 1994
(AGARD-LS-197) Copyright Avail: CASI HC A03/MF A02

Wake turbulence is a misnomer. Turbulence implies a random process whereas the term 'wake turbulence' refers to the hazard posed to smaller airplanes by the ordered, rotational flow in the trailing vortex systems behind larger airplanes. This lecture begins by examining the relationship of aircraft size, geometry and operating conditions to the strength of an aircraft's trailing vortex system. Next, the velocity field initially induced close behind the generating airplane by its trailing vortex system is defined. This is followed by a discussion of the various ways in which a vortex system can dissipate and the many factors which affect the dissipation. In particular, the effects of atmospheric turbulence, ground proximity and vortex bursting on the ensuing behavior of the vortex system are considered. The paper continues with a study of the dynamics of an aircraft encountering the wake of a larger airplane. The degree to which an aircraft is threatened by a given vortex system of known characteristics is analyzed and the hazard posed by a given vortex system to a following aircraft quantified. Finally, the paper concludes with recommendations on possible ways to alleviate the safety and operational problems associated with wake turbulence. Author

N95-16563# National Technical Univ., Athens (Greece). Lab. of Thermal Turbomachines.
SINGLE-PASS METHOD FOR THE SOLUTION OF INVERSE POTENTIAL AND ROTATIONAL PROBLEMS. PART 1: 2-D AND QUASI 3-D THEORY AND APPLICATION
P. CHAVIAROPOULOS, V. DEDOUSSIS, and K. D. PAPAILIOU *In* AGARD, Optimum Design Methods for Aerodynamics 19 p (SEE N95-16562 04-05) Nov. 1994
(AGARD-R-803) Copyright Avail: CASI HC A03/MF A03

A methodology for the solution of the 2-D and 3-D inverse inviscid subsonic flow problem is introduced. The proposed methodology handles the 2-D and axisymmetric rotational and the 3-D potential target pressure problem in a single-pass manner. The method is based on a potential function/stream function formulation where the physical space is mapped onto a natural one using the potential and stream function(s) as body-fitted coordinates. A novel procedure based on differential geometry and generalized tensor analysis arguments is employed to formulate the method in a modular way. The governing equations for the inverse problem are derived through the metrics compatibility condition on the natural space. Geometry is determined by integrating generalized Frenet equations along the natural coordinate lines. Rotationality, when present, is due to incoming (stagnation) thermodynamic quantities and/or preswirl gradients. The Clebsch formulation is, then, adopted to decompose the velocity field into a potential and a rotational part. To validate the method inverse calculation results are compared to results of direct 'reproduction' calculations. The design procedure of some optimized shapes is also presented. Part 1 of this lecture focuses on 2-D and axisymmetric inverse potential or rotational flow problems, while the fully 3-D inverse potential problem is considered in Part 2. Author

N95-16564# National Technical Univ., Athens (Greece). Lab. of Thermal Turbomachines.
SINGLE-PASS METHOD FOR THE SOLUTION OF INVERSE POTENTIAL AND ROTATIONAL PROBLEMS. PART 2: FULLY 3-D POTENTIAL THEORY AND APPLICATIONS
P. CHAVIAROPOULOS, V. DEDOUSSIS, and K. D. PAPAILIOU *In* AGARD, Optimum Design Methods for Aerodynamics 14 p (SEE N95-16562 04-05) Nov. 1994
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A potential function/stream function formulation is introduced for the solution of the fully 3-D inverse potential 'target pressure' problem. Potential function and two stream vectors are used as the independent natural coordinates, whilst the velocity magnitude, as well as, the aspect ratio and the cross-section angle of the elementary stream tubes are assumed to be the dependent ones. A novel procedure based on differential geometry is employed to formulate the method. The governing differential equations are derived by requiring the curvature tensor of the flat 3-D physical Euclidean space, expressed in terms of the curvilinear natural coordinates, to be zero. The resulting equations are discussed and investigated with particular emphasis to the existence and uniqueness of their solution. It is shown that the general 3-D inverse potential problem with target pressure boundary conditions only, is ill-posed accepting multiple solutions. This multiplicity is alleviated by considering elementary stream tubes with orthogonal cross-sections. The assumption of orthogonal stream surfaces reduces the number of dependent variables by one, simplifying the governing equations to an elliptic PDE, for the the velocity magnitude and to a second order ODE for the stream tube aspect ratio. The solution of these two equations provides the flow field. Geometry is determined independently by integrating Frenet equations along the natural coordinate lines, after the flow field has been calculated. The numerical implementation as well as validation test cases for the proposed inverse methodology are presented in the last part of the lecture. Author

N95-17846# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
A SELECTION OF EXPERIMENTAL TEST CASES FOR THE VALIDATION OF CFD CODES, VOLUME 2 [RECUEIL DE CAS D'ESSAI EXPERIMENTAUX POUR LA VALIDATION DES CODES DE L'AERODYNAMIQUE, VOLUME 2]
Aug. 1994 577 p See also 95N-14201 and diskette supplement AGARD-AR-303-Suppl
(AGARD-AR-303-VOL-2; ISBN-92-836-1003-2) Copyright Avail: CASI HC A25/MF A06

This report presents the results of a study by Working Group 14 of the AGARD Fluid Dynamics Panel. The thirty nine test cases that are documented cover the subsonic, transonic, and supersonic flow regimes and five classes of geometries. Included in the five classes of geometries are: Two Dimensional Airfoils; Three Dimensional Wings, designed for predominantly attached flow conditions; Slender Bodies, typical of missile type configurations; Delta Wings, characterized by a conical type of vortex flow; and Complex Configurations, either in a geometrical sense or because of complicated flow interactions. The report is presented in two volumes. Volume 1 provides a review of the theoretical and experimental requirements, a general introduction, summary of the test cases and recommendations for the future. Volume 2 contains detailed information on the test cases. Relevant data has been compiled on floppy disks. For individual titles, see N95-17847 through N95-17885.

N95-17848# Defence Research Agency, Farnborough, Hampshire (England).
MEASUREMENTS ON A TWO-DIMENSIONAL AEROFOIL WITH HIGH-LIFT DEVICES
I. R. M. MOIR *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 12 p (SEE N95-17846 04-02) Aug. 1994
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The tests detailed in this submission were carried out by the former British Aircraft Corporation in support of the National High Lift Programme. This Programme was a collaborative project between the Royal Aerospace Establishment Farnborough (now part of the the DRA) and the aircraft industry with the aim of increasing the understanding and knowledge of all aspects of high-lift systems, and to provide a fund of data which would benefit the design of future transport aircraft. Wind-Tunnel tests were carried out on four models: (1) A 3-D half model (RAE); (2) a swept panel wing (HSA Hatfield); (3) a quasi-2D (end-plate) model (BAC Weybridge); and (4) a 2D model (BAC Weybridge). BAC Warton also carried out structural analyses on various leading-edge and trailing-edge devices. The present cases are results from the 2D tests which covered investigations into two leading-edge and two trailing-edge devices. The model had a supercritical aerofoil section, a chord of 0.7635m, and was mounted between turnables in the floor and roof of the BAC 3.96m x 2.74m low-speed wind-tunnel. Two-dimensional conditions were maintained by local suction around the wing/wall junctions. Surface pressures were measured on all the components of the wing, at two spanwise stations, one near the tunnel centerline, and one near the roof. These pressures were integrated to give overall lift, drag and pitching moment coefficients. A pilot/static transverse through the wake provided the total momentum deficit. Traverses perpendicular to the wing surface at various chordwise locations provided information on wake and boundary layer development and interaction. Flow visualization was provided by tufting of the wing surfaces. Author

N95-17849# Defence Research Agency, Bedford (England).
INVESTIGATION OF THE FLOW OVER A SERIES OF 14 PERCENT-THICK SUPERCRITICAL AEROFOILS WITH SIGNIFICANT REAR CAMBER
P. R. ASHILL *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 13 p (SEE N95-17846 04-02) Aug. 1994
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The experiments described in this submission were performed on various airfoil sections, all of 14 percent thickness/chord ratio and with significant rear camber. The main aim was to obtain an improved understanding of viscous effects on flows over airfoils with severe adverse pressure gradients. Such gradients can be found at the rear airfoils with significant rear camber and at the foot of shock waves. The tests were performed in the 8ft x 8ft Pressurized, Subsonic/Supersonic Wind Tunnel at the Defense Research Agency (DRA, formerly the Royal Aerospace Establishment) Bedford between November 1976 and February 1982. This wind tunnel has solid walls and, since the airfoil chord to tunnel height is relatively large (0.26), the data are strictly not correctable. This was recognized from the outset, the main concern of the investigation being studying flows rather than performing tests on a prescribed shape. However, the wall boundary conditions are well defined and so the data may be useful for validating CFD codes which include allowance for the wind-tunnel walls. In addition, measurements were made of the static pressures on the roof and floor of the working section, providing an independent check on the accuracy of the representation of the walls in any CFD method. Despite the caveat above about correctability, it is believed that the cases presented having weak shock waves may be used to assess free-air calculation methods provided that allowance is made in the calculation for wall-induced camber. Cases suitable for such work are highlighted in Section 6.2 where details are also given of the camber correction. Author

N95-17850# National Research Council of Canada, Ottawa (Ontario). Inst. for Aerospace Research.
SURFACE PRESSURE AND WAKE DRAG MEASUREMENTS ON THE BOEING A4 AIRFOIL IN THE IAR 1.5X1.5M WIND TUNNEL FACILITY
D. J. JONES and Y. NISHIMURA *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 10 p (SEE N95-17846 04-02) Aug. 1994
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This 10.2 percent maximum thickness to chord airfoil has become a standard airfoil for Boeing wind tunnel tests in the IAR 1.5 X 1.5m facility. In order to study wall constraint effects, several different chord lengths have been used in the narrow span (38.1 cm) IAR facility and a 30.5 cm chord model was tested in the 1.5 wide facility. The latter data from the wide span facility are presented here. This data has a small sidewall correction while the upper and lower walls are accounted for using Mokry's wall correction procedures. Transition was fixed at 10 percent and all runs were made at a chord Reynolds number of 14 million. The tests were carried out in June-July, 1991. Author

N95-17851# McDonnell-Douglas Corp., Long Beach, CA.
2-D AILERON EFFECTIVENESS STUDY
V. D. CHIN, C. J. DOMINIK, F. T. LYNCH, and D. L. RODRIGUEZ *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 20 p (SEE N95-17846 04-02) Aug. 1994
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The experimental data described in this contribution were obtained in the IAR High Reynolds Number 60 x 15 (1.5m x 0.38m) Two-Dimensional Test Facility. The purpose of the experiment was to investigate the effects of Reynolds number and Mach number on aileron effectiveness and to evaluate effectiveness of viscous scaling techniques that attempt to simulate flow at higher Reynolds numbers. The advent of the modern transport wing has prompted a renewed interest in the transonic characteristics of ailerons. In addition to their traditional role of lateral (roll) control, aileron are used for wing load alleviation and to improve cruise performance through the 'drooped aileron' concept. An understanding of the prevailing flow physics which limit the transonic performance of ailerons is necessary for the successful design of a control system that satisfies the multi-role requirements of the aileron. Results showed a linear variation of lift for upward trailing edge deflections but a highly nonlinear variation for downward deflections. This nonlinear behavior, equivalent to a loss in aileron effectiveness, became worse at higher angles of attack and higher Mach numbers. In addition, the viscous scaling technique that was used at lower Reynolds numbers was found to be inadequate for modeling flow at higher Reynolds numbers. The data acquired from this test were for a series of aileron deflections varying from -5 to +5 deg at Mach numbers of 0.717 and 0.746 and chord Reynolds numbers of 5, 15, and 25 million. The following types of data were obtained:

airfoil surface pressure distributions; wake drag, which was determined by wake transversing probes; lift and drag forces and pitching moment, which were determined by force balance readings and surface pressure integrations; and floor and ceiling pressure distributions, which were used to compute wall interference effects. One of the difficulties in wind tunnel testing is accounting for the effects of wall interference to reinterpret the data for 'free air' conditions. Corrections for interference effects of the floor and ceiling and for the wall sidewall boundary layer effects were applied to the data. The data are available corrected for floor and ceiling effects, and corrected for both floor and ceiling interference and sidewall boundary layer effects. Author

N95-17852# Technische Hochschule, Aachen (Germany). Aerodynamisches Inst.

INVESTIGATION OF AN NLF(1)-0416 AIRFOIL IN COMPRESSIBLE SUBSONIC FLOW

P. GUNTERMANN and G. DIETZ *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 10 p (SEE N95-17846 04-02) Aug. 1994
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The data presented in this contribution were obtained in the 40 x 40 sq cm Transonic Wind Tunnel at the Aerodynamisches Institut of the RWTH Aachen within the research program 'Entwicklung von Berechnungsverfahren fur Probleme der Stromungsmechanik' sponsored by the Stiftung Volkswagenwerk. The aim of the experimental part of the research program was to investigate the influence of compressibility on the location of transition. For this purpose a natural-laminar-flow airfoil NLF (1)-0416, designed for incompressible flow, was investigated. Starting with incompressible free stream conditions the Mach number was increased until transonic flow was obtained. The experiments on the NLF(1)-0416 should provide aerodynamical forces such as lift and drag and data concerning the location and the underlying physical mechanism of transition. Therefore different measuring techniques, e.g. liquid crystal coating and multi-sensor hot-film technique, were tested. To verify the existence of a laminar separation bubble the topology of the boundary layer was visualized. Regarding the different turbulence levels there is a good agreement of the experimental results with those obtained at NASA-Langley, which are available up to Mach numbers of 0.4. Numerical results correspond to the experiments at higher Mach numbers too. Experiments were carried out to get information about the influence of small disturbances of the profile surface on the pressure distribution, the drag, and the location of transition. In continuation of this research a wind tunnel model with adjustable geometry of its upper surface was developed and manufactured. The influence of small surface variations on the location of transition or separation will be investigated experimentally, but these tests are not part of the presented data set. Author

N95-17853# Technische Hogeschool, Delft (Netherlands). Low Speed Aerodynamics Lab.

EXPERIMENTS IN THE TRAILING EDGE FLOW OF AN NLR 7702 AIRFOIL

L. H. J. ABSIL and D. M. PASSCHIER *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 16 p (SEE N95-17846 04-02) Aug. 1994
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Detailed mean flow and turbulence properties are presented of the flow in the vicinity of an airfoil trailing edge, to provide data for the development of turbulence models and the validation of computational methods. Author

N95-17854# National Aerospace Lab., Amsterdam (Netherlands).

TWO-DIMENSIONAL 16.5 PERCENT THICK SUPERCRITICAL AIRFOIL NLR 7301

S. O. T. H. HAN *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 11 p (SEE N95-17846 04-02) Aug. 1994
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This thick supercritical airfoil designed for a lift-coefficient of 0.595 at a Mach number of 0.721 (potential flow conditions) was an early NLR design of a supercritical airfoil made in 1973. The airfoil was designed with the hodograph method and has a rather blunt nose with a roof-top type pressure distribution. A typical other feature of this airfoil is that it is highly rear loaded, both on the upper surface and on the lower surface. Because of this rear loading, the airfoil is close to trailing edge separation on the upper surface and separation in the cove region around 70% chord at the lower surface. Tests have been made originally in the NLR (Transonic) Pilot Tunnel at a Reynolds number of 2.2 million (the design condition). The results of these tests have been included in AGARDograph AR-138. At about the same time test were made in the Compressible Flow Facility CFD) of Lockheed (Georgia, USA) for the Reynolds number of 10, 20 and 30 million. In the eighties, when more advanced computer codes became available that could cope with airfoils that experienced a limited extent of separation, there was an urgent need for reliable data to validate the computer codes for these conditions. Also, the problem of scaling (low Reynolds number) wind tunnel tests to (the much higher) flight Reynolds numbers raised (again) considerably interest. For both reasons it was decided to repeat the original NLR 7301 experiments on a larger two-dimensional model in the large transonic wind tunnel HST of NLR. The tests covered the low speed and transonic speed regimes whereas part of the measurements was performed at constant lift for range of Reynolds numbers of study the indirect Reynolds number effects in more detail. Author

N95-17855# National Aerospace Lab., Amsterdam (Netherlands).

LOW-SPEED SURFACE PRESSURE AND BOUNDARY LAYER MEASUREMENT DATA FOR THE NLR 7301 AIRFOIL SECTION WITH TRAILING EDGE FLAP

B. VANDENBERG and J. H. M. GOODEN *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 12 p (SEE N95-17846 04-02) Aug. 1994
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Test data are given for a two-dimensional wing flap configuration, which has been so designed that nowhere flow separations occur, apart from a small laminar separation bubble on the wing nose. The 32% chord trailing edge flap is deflected 20 deg. Two widths of the gap between wing and flap have been applied, with mixing of the wing wake and flap boundary layer occurring with the smaller gap. The experiment has been carried out at a Reynolds number Re, c = 2.51 * E6 and a Mach number of about Ma = 0.185. The measurements comprise surface pressure data, from which lift and pitching moment coefficients were calculated, at various angles of attack from zero up to beyond stall. At three angles of attack the drag has been determined from wake traverses. At these angles mean flow measurements in the boundary layer and wake have been executed at 16 stations. In addition turbulence data were obtained at 5 stations in the wing wake above the flap. Surface flow visualization data are also available. Author

N95-17856# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).

DATA FROM THE GARTEUR (AD) ACTION GROUP 02 AIRFOIL CAST 7/DOA1 EXPERIMENTS

A. MIGNOSI, J. P. ARCHAMBAUD, and E. STANEWSKY (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany.) *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 12 p (SEE N95-17846 04-02) Aug. 1994
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In order to gain a better understanding of the various forms and the magnitude of wind tunnel interferences that may arise in two-dimensional testing and to find improved methods of correction, a GARTEur Action Group was formed in 1979 with the primary objectives of (1) comparing test results obtained with one airfoil (CAST 7) in a number of facilities in order to assess wall interference in the individual tunnels and to assess the accuracy of correction methods currently used and (2) evaluating three-dimensional interference effects associated with the side wall boundary layer. The wind tunnels considered consisted of five conventional tunnels with either slotted or perforated test section walls and two adaptive wall wind tunnels. Based on a comparison of the results from these tunnels, it was concluded that for these

two-dimensional airfoil tests the freestream conditions, Mach number and angle of attack, were generally predicted with an accuracy of delta M infinity = plus or minus 0.002 and delta alpha = plus or minus 0.1 deg to plus or minus 0.05 deg, respectively, and the lift and drag coefficients with an accuracy of delta C(sub L) = plus or minus 0.015 and delta C(sub D) = plus or minus 0.0003 deg, respectively. For the adaptive wall wind tunnel T2 of ONERA/CERT the accuracy in freestream conditions was determined to be delta M infinity = plus or minus 0.001 and delta alpha = plus or minus 0.03 deg. Due to their relatively high accuracy, only the ONERA T2 adaptive wall tests are considered hereafter. The data, obtained with well defined boundary conditions, are believed to be the most suitable for CFD - assessment.

Author

N95-17857# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).

OAT15A AIRFOIL DATA

A. M. RODDE and J. P. ARCHAMBAUD *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 13 p (SEE N95-17846 04-02) Aug. 1994

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The OAT15A airfoil is a supercritical airfoil for transport aircraft designed a few years ago within the framework of an ONERA/Aerospatiale joint programme devoted to the study of various designs. The design point is M = 0.73, C(sub L) = 0.65 and the thickness to chord ratio of the airfoil is 12.3 percent. The tests which were performed in the ONERA/CERT T2 wind tunnel were devoted to the Reynolds number effects on the airfoil performance. These effects were investigated within the range 3-20 10(exp 6) taking advantage of the cryogenic capability of the tunnel. The adaptive top and bottom walls of the tunnel give quasi free air conditions. However some sidewall effects are present and are taken into account in the correction procedure. Tests performed on another model in the S3MA wind tunnel with perforated top and bottom walls show good agreement with the T2 tests which give more confidence concerning the quality of the data. The proposed test cases concern mainly pressure distributions for various Reynolds numbers with fixed transition. However for a selected number of test cases boundary layer measurements with an external probe and LDV flow field data are also given. The set of data can be used for different purposes: (1) computer code capability for the prediction of Reynolds number effect; and (2) detailed 2D computer code assessment.

Author (revised)

N95-17858*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

A SUPERCRITICAL AIRFOIL EXPERIMENT

GEORGE G. MATEER, H. LEE SEEGMILLER, LAWRENCE A. HAND, and JOACHIM SZODRUCH (Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen, Germany.) *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 12 p (SEE N95-17846 04-02) Aug. 1994

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The purpose of this investigation is to provide a comprehensive data base for the validation of numerical simulations. The initial results of the study (single angle of attack) were presented in ref. 1, where the effects of various parameters and the adequacies of selected turbulence models were discussed. The objective of the present paper is to provide a tabulation of the experimental data. The data were obtained in the two-dimensional, transonic flowfield surrounding a supercritical airfoil. A variety of flows were studied in which the boundary layer at the trailing edge of the model was either attached or separated. Unsteady flows were avoided by controlling the Mach number and angle of attack. Surface pressures were measured on both the model and wind tunnel walls, and the flowfield surrounding the model was documented using a laser Doppler velocimeter (LDV). Although wall interference could not be completely eliminated, its effect was minimized by employing the following techniques. Sidewall boundary layers were reduced by aspiration, and upper and lower walls were contoured to accommodate the flow around the model and the boundary-layer growth on the tunnel walls. A data base with minimal interference from a tunnel with solid walls provides an ideal basis for evaluating the development of codes for the transonic speed range because the codes can include the wall boundary conditions more precisely than interference corrections can be made to the data sets.

Author

N95-17859# Boeing Commercial Airplane Co., Seattle, WA.

TWO-DIMENSIONAL HIGH-LIFT AIRFOIL DATA FOR CFD CODE VALIDATION

G. W. BRUNE *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 13 p (SEE N95-17846 04-02) Aug. 1994

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The purpose of the experimental investigation summarized below was to provide a complete data set for the validation of two-dimensional multi-element airfoil computer codes. The airfoil model used for this investigation features four elements including a double slotted trailing edge flap and a slotted leading edge device representing a section of a transport wing in high-lift configuration with take-off flap setting. The leading edge flap was tested in a nonoptimum setting in order to produce a thick confluent boundary layer on the upper airfoil surface. In this wind tunnel experiment, all data were measured on a single high-lift airfoil configuration with a fixed flap setting at one tunnel freestream condition. Emphasis was placed on the acquisition of a few high quality airfoil data with many repeat runs and redundant measurements. Measured data comprise airfoil lift, drag, pitching moment, surface pressures, mean velocity profiles and Reynolds stresses of the confluent boundary layer. The data was obtained in the Boeing Research Wind Tunnel located in Seattle at 0.11 Mach number and 1.55 million Reynolds number based on tunnel freestream velocity and a flaps-up airfoil chord of 0.6096 m (2 ft). Care was taken to achieve a close approximation to two-dimensional flow by means of turntable and tunnel side wall blowing. Two-dimensional flow was verified by comparing boundary layer mean velocity and turbulence profiles at several spanwise stations, and by various surface flow visualizations methods. In addition, lift curves from balance measurements and an integration of surface pressures were compared. Confluent boundary layer measurements were conducted employing a Pitot probe and hot wires. Probes were mounted on a mechanical traverser designed to minimize disturbances of overall airfoil circulation and of the local flow at the measuring station. Author

N95-17860# Defence Research Agency, Farnborough, Hampshire (England). Aerodynamics and Propulsion Dept.

MEASUREMENTS OF THE FLOW OVER A LOW ASPECT-RATIO WING IN THE MACH NUMBER RANGE 0.6 TO 0.87 FOR THE PURPOSE OF VALIDATION OF COMPUTATIONAL METHODS. PART 1: WING DESIGN, MODEL CONSTRUCTION, SURFACE FLOW. PART 2: MEAN FLOW IN THE BOUNDARY LAYER AND WAKE, 4 TEST CASES

M. C. P. FIRMIN and M. A. MCDONALD *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 18 p (SEE N95-17846 04-02) Aug. 1994

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The experiments presented should improve the understanding of the flow over a wing as the speed is increased towards the buffet and separation boundaries. These boundaries limit the flight envelopes of both military and civil aircraft, and the measurements reported will allow Computational Fluid Dynamic (CFD) methods for viscous flow to be validated. The measurements are reported in two documents (Parts 1 & 2) giving detailed measurements of the subsonic free stream flow over a low aspect-ratio wing (RAE Model 2155) at conditions where the boundary layers are subjected to severe adverse pressure gradients. Part 1 provides measurements of pressure distributions on both the wing and on the tunnel walls for a wide range of Mach numbers and lift coefficients, as well as of wing surface skin friction and surface flow direction measurements for four test cases, while Part 2 contains detailed mean flow measurements within the shear layers. For this detailed study, the same four test cases have been used, as presented in Part 1. They were chosen to provide examples of flows with severe adverse pressure gradients, including those with shock waves, and leading in some cases to separation. Author

N95-17861# Defence Research Agency, Bedford (England).
DETAILED STUDY AT SUPERSONIC SPEEDS OF THE FLOW AROUND DELTA WINGS
M. J. SIMMONS *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 17 p (SEE N95-17846 04-02) Aug. 1994
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The tests described in this submission were made on two half-models of delta-wing/body configuration suitable for supersonic combat aircraft. The aim of the program of work was to improve the understanding of supersonic flows over wing with rounded leading edges. The reason for choosing the large half-model design were: (1) the attainment of high chordal Reynolds numbers; (2) the facility to make detailed flow measurements; and (3) the ability to manufacture the large wing to the desired model accuracy with conventional machine tolerances. The last requirement is particularly important in the highly-curved region of the leading edge which controls the development of transonic flows on the upper surface. Both wings are of the same quasi-delta planform of 60 leading edge sweep and thickness form of 4% thickness/chord ratio but with differing camber distributions. Wing A has a complex camber surface with camber in both spanwise and streamwise planes. Wing C has an umcambered symmetrical section and was used as a datum case for the study. The only design constraint on model size was the need to ensure that the flow over the wing was not disturbed by shock-wave reflections from the solid walls of the tunnel. The tests were performed in the 8ft x 8ft Pressurized, Subsonic/Supersonic Wind Tunnel at the Defense Research Agency (DRA Aerospace Division, formerly the Royal Aerospace Establishment) Bedford in July 1985.
Author (revised)

N95-17862# Defence Research Agency, Bedford (England).
PRESSURE DISTRIBUTIONS ON RESEARCH WING W4 MOUNTED ON AN AXISYMMETRIC BODY
J. L. FULKER *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 12 p (SEE N95-17846 04-02) Aug. 1994
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The experiments described in this submission were performed on a wing-body configuration suitable for a civil transport aircraft. When the wing was designed (1972) it was recognized that, in order to achieve an advance in technology, a significant increase in rear loading would be required compared to that of earlier designs. As a consequence, the boundary layer conditions close to the trailing edge on the upper surface were expected to be more adverse than in previous designs. This requirement led to the need for a high test Reynolds number, which was achieved by testing a large half model in the Defense Research Agency (DRA) 8ft x 8ft Wind Tunnel at Reynolds numbers, based on geometric mean chord, of up to 15 x 10(exp 6). Complementary tests were also performed on a smaller complete model in order to provide an accurate assessment of the drag characteristics of the wing. The wing was designed to have a weak shock wave near mid chord on the upper surface at the cruise condition (C(sub L) = 0.32, M = 0.78). The overall aims of the investigation were to obtain an improved understanding of the behavior of the flow over wings of this type over a wide range of subsonic Mach numbers and Reynolds numbers. The tests were performed during 1977 on the complete model and 1978 on the half model. The wind tunnel has solid walls, and since the models are relatively large, the data are strictly not correctable. However, the wall boundary conditions are well defined and so the data may be useful for validating CFD codes which include allowance for the wind-tunnel walls. In addition measurements were made on the static pressures on the roof and floor of the working section, providing an independent check on the accuracy of the representation of the walls in any CFD method.
Derived from text

N95-17864# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany).
DLR-F5: TEST WING FOR CFD AND APPLIED AERODYNAMICS
H. SOBIECZKY *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 11 p (SEE N95-17846 04-02) Aug. 1994
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A swept wing with symmetrical sections was originally created to serve two purposes. First, the surface generator used for data definition was under development for aerodynamic design and optimization. The wing created was intended therefore to be a selected case of a whole family of configurations obtained by variation of the input parameters. Aerodynamic design and optimization strategies call for such variations. Second, CFD code development needs both accurate test case geometries as well as experimental results from wind tunnels. The latter usually suffer from corrections which still might suit practical purposes of measuring aerodynamic coefficients but fall short of the requirement to define the flow conditions to the same accuracy as geometrical boundaries are known. Using the generator software, a compromise was chosen by including the closed wind tunnel wall geometry as a channel boundary surrounding an aerodynamic component. In order to also avoid model support problems, a wing half model mounted on and including a splitter plate was used as 'configuration.' Geometry of the flow boundaries was completely defined through the simple rectangular channel geometry completed by chosen inlet and exit planes. Flow data were required at these planes to formulate a boundary value problem for CFD. In a workshop to compare CFD results with the first test case experiment (1986), partners had obtained and used a computer code to generate the wing and the wind tunnel boundary conditions, along with the absolutely necessary parameters to formulate fluid dynamic boundary conditions for the Navier-Stokes equations. This software is a simplified version of the geometry generator for aerospace configurations and CFD grid generation which has since been further developed as an industrial tool for design aerodynamics. The experiment and the refined half-model technique was published and the results of the workshop, comparing numerical results, have been summarized. Based on these results we may conclude that for CFD this test case turns out to be a complicated one basically because of the observed viscous flow phenomena on the wing. On the other hand, the definition of the complete boundary value problem makes the case rather unique and, with the help of generator software and experimental data, easy to implement for CFD validation. The workshop software and experimental results for surface pressure distributions is made available in one package.
Derived from text

N95-17865*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
LOW ASPECT RATIO WING EXPERIMENT
MIKE OLSEN and H. LEE SEEGMILLER *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 11 p (SEE N95-17846 04-02) Aug. 1994
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This test was initiated to provide validation data on low aspect ratio wings at transonic speeds. The test was conducted so that the data obtained would be useful in the validation of codes, and all boundary condition data required would be measured as part of the test. During the conduct of the test, the measured quantities were checked for repeatability, and when the data would not repeat, the cause was tracked down and either eliminated or included in the measurement uncertainty. The accuracy of the data was in the end limited by wall imperfections of the wind tunnel in which the test was run.
Derived from text

N95-17866# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Hauptabeilung Windkanaele.
WIND TUNNEL INVESTIGATIONS OF THE APPEARANCE OF SHOCKS IN THE WINDWARD REGION OF BODIES WITH CIRCULAR CROSS SECTION AT ANGLE OF ATTACK
H. ESCH *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 16 p (SEE N95-17846 04-02) Aug. 1994
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Originally the model was designed to investigate differences in the interference of fuselage and control surfaces attached to bodies of circular and rectangular cross sections. During the test it was found difficult to define the interference since the reference configuration, the isolated body without controls, showed some disturbances in the pressure distribution at certain combinations of Mach number and angle of attack. These disturbances are connected with the appearance of shock waves on the windward side of isolated circular bodies. By checking schlieren pictures made during earlier test series of missiles the range could be defined in which this type of shock occurs. Pressure distribution measurements were made in order to find an explanation for the formation of the shocks and their bending into the windward region. It is believed that three conditions must be fulfilled: (1) Crossflow Mach number must be high enough that a shock forms in front of the wedge-like primary separation. (2) The primary separation line must move towards the windward side of the body. As a result the local Mach number normal to the separation line decreases, and eventually the shock detaches - if the crossflow Mach number is not too high. (3) When the local surface Mach number normal to the body axis is less than one, the disturbances propagates towards the windward region of the body. In some cases this type of disturbance may lead to confusion especially when there are not enough pressure taps: in the pressure distribution one finds only one or two peaks and from this, one cannot identify the shock trace. The model is extremely simple and thus the generation of a grid should not be too expensive. The data are considered valuable for CFD validation but on the other hand CFD should be useful to get more information of the outer flow field and further insight into this more fundamental flow phenomenon. Derived from text

N95-17868# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany).
FORCE AND PRESSURE DATA OF AN OGIVE-NOSED SLENDER BODY AT HIGH ANGLES OF ATTACK AND DIFFERENT REYNOLDS NUMBERS
K. HARTMANN *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 13 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

Force, moment, flow field, and pressure measurements (steady and unsteady) were carried out on an ogive-nosed circular cylinder body with a smooth surface. The tests were performed in the two open jet low speed wind tunnels of the DLR in Gottingen (NWG, test section size 3 m x 3 m) and in Braunschweig (NWB, test section size 2.8 m x 3.25 m). A body diameter of D = 200 mm was chosen to achieve Reynolds numbers as high as possible at the maximum speed in these tunnels. The tests comprise angles of attack from 0 to 90 deg and Reynolds numbers of 2.5 x 10(exp 5), 3.7 x 10(exp 5), and 7.7 x 10(exp 5) (based on body diameter and freestream conditions). For six angles of attack between 20 and 70 deg the dependence on different roll positions of the body was systematically investigated with a complete coverage of 360 deg. In some cases the turbulence level of the freestream was varied. The body vortices were visualized in a water towing tank using hydrogen bubbles and in the wind tunnel with the aid of smoke and a laser light sheet. Derived from text

N95-17870# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SUPERSONIC VORTEX FLOW AROUND A MISSILE BODY
D. BARBERIS *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 11 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

Boundary-layer separation occurring on a missile body at moderate or high angle of incidence leads to the formation of well organized vortical structures, especially at supersonic flight Mach numbers. Even though a certain number of experimental results are available for this type of flow, none of the published data provide complete information for a supersonic flow. A experimental study of the flowfield around a 3 caliber tangent ogive-cylinder body in a supersonic flow has been carried out to provide a consistent description of the flow. This experiment includes oil flow visualizations, primary separation line determination, surface pressure measurements and five hole pressure probe surveys for a Mach number of 2 and an angle of incidence varying from 0 to 20 deg. Results are obtained for a natural and fixed transition. Author

N95-17872# National Aerospace Lab., Amsterdam (Netherlands).
WIND TUNNEL TEST ON A 65 DEG DELTA WING WITH A SHARP OR ROUNDED LEADING EDGE: THE INTERNATIONAL VORTEX FLOW EXPERIMENT
A. ELSENAAR *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 18 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

The windtunnel tests carried out on this model resulted from an international co-operation that involved the aeronautical laboratories AFWAL (US), DLR (Germany), FFA (Sweden), NLR (The Netherlands) and the Universities of Braunschweig (Germany) and Delft (The Netherlands). It was the basic aim of these measurements to provide detailed pressure and flow field data on a 65 deg delta wing configuration of a generic shape for the validation of CFD methods, notably Euler methods. For this reason one of the basic configurations had a sharp leading edge. However, there was also considerable interest for configurations with more realistic features and therefore other configurations were added. These featured a wing with a smaller sweep angle (55 instead of 65 deg), a rounded instead of a sharp leading edge shape, a drooped leading edge and the addition of a canard wing. The windtunnel tests were made in different wind tunnels with different models. They covered a large range of flow conditions and measuring techniques (including force, pressure and flow field measurements). The test case to be described here covers only the force and pressure measurements as carried out at NLR in the transonic windtunnel HST and the supersonic windtunnel SST. The measurements executed at DLR, including flow field measurements, can be found in case D-4. Author

N95-17873# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
DELTA-WING MODEL
D. BARBERIS *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 11 p (SEE N95-17846 04-02) Aug. 1994
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A detailed study has been made on the flow around a 75 sweep angle delta wing to provide reference material or numerical codes. Experiments were carried out in the F2 wind tunnel of the ONERA Le Fauga - Mauzac Centre. Firstly an examination of the surface flow properties was carried out using surface pressure measurements an surface flow visualizations with a viscous coating. The angle of incidence was varied between 5 and 30 deg and the upstream velocity between 10 and 75 m/s. Secondly,the aerodynamic field was characterized by means of laser tomography visualizations and surveys with a two component laser Doppler velocimeter system. Mean and fluctuating velocity fields were determined in several vertical planes normal to the wind tunnel longitudinal axis. These measurements were carried out for an

angle of incidence of 20 deg and for two values of the upstream velocity (24 m/s and 40 m/s). Author

N95-17874# Technische Hogeschool, Delft (Netherlands). Faculty of Aerospace Engineering.
EXPERIMENTAL INVESTIGATION OF THE VORTEX FLOW OVER A 76/60-DEG DOUBLE DELTA WING
N. G. VERHAAGEN and J. E. J. MASELAND *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 15 p (SEE N95-17846 04-02) Aug. 1994
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Data was obtained from a low-speed wind-tunnel experiment carried out on a sharp-edged 76/60-deg double-delta wing. The objective of the investigation was to generate data on the vortex interaction downstream of the strake-wing leading-edge kink of a double-delta wing. An oil-flow and laserlight-sheet technique was used to visualize the flow on and off the surface of the wing. Balance measurements were performed to determine the forces and moments acting on the wing. In addition, the pressure on the upper surface of the wing was measured at several wing chordwise stations. Using a thin five-hole probe, the flowfield over the wing panel was surveyed in detail for an incidence of 20 deg. The data provide information on the interaction process of the wing and strake vortex as well as the development of the secondary separation downstream of the leading-edge kink. Author

N95-17875# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany).
WIND TUNNEL TEST ON A 65 DEG DELTA WING WITH ROUNDED LEADING EDGES: THE INTERNATIONAL VORTEX FLOW EXPERIMENT
K. HARTMANN, K. A. BUETEFISCH, and H. PSZOLLA *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 12 p (SEE N95-17846 04-02) Aug. 1994
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The wind tunnel tests carried out on this model resulted from an international cooperation that involved the aeronautical laboratories AFWAL (US), DLR (Germany), FFA (Sweden), NLR (The Netherlands) and the Universities of Braunschweig (Germany) and Delft (The Netherlands). It was the basic aim of these measurements to provide detailed pressure and flow field data on a 65 deg delta wing configuration of a generic shape for the validation of CFD methods, notably Euler methods. For this reason one of the basic configurations had a sharp leading edge. However, there was also considerable interest for configurations with more realistic features and therefore other configurations were added. These featured a wing with a smaller sweep angle (55 instead of 65 deg), a rounded instead of a sharp leading edge shape, a drooped leading edge and the addition of a canard wing. The wind tunnel tests were made in different wind tunnels with different models. They covered a large range of flow conditions and measuring techniques including force, pressure and flow field measurements. The test case to be described here covers the force, pressure and flow field measurements and flow visualization as carried out at DLR in the transonic wind tunnel TWG on the smaller scale model with round leading edges. This configuration was designed and manufactured by the MBB company in Germany. Author

N95-17876# Aircraft Research Association Ltd., Bedford (England).
INVESTIGATION OF THE FLOW DEVELOPMENT ON A HIGHLY SWEPT CANARD/WING RESEARCH MODEL WITH SEGMENTED LEADING- AND TRAILING-EDGE FLAPS
D. STANNILAND *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 18 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

The results included in this submission are drawn from the extensive testing which has been carried out on a simple canard/wing research model with a low aspect ratio (2.3), highly swept (58 deg) wing with leading- and trailing-edge flaps. The purpose of these tests was to improve the understanding of the flow development of this class of configuration, to validate the CFD method and philosophy used for the wing design and to provide and extensive data base of pressure data on a precisely specified model geometry for the validation of CFD methods which are capable of handling more complex geometries. The wing was designed using an FP wing/body code, aiming for attached flow at a high subsonic maneuver design point. This results in a highly cambered and twisted wing with a complex flow breakdown on the upper surface. The use of a segmented leading-edge flap means that the vortical flow develops as a series of part-span vortices, even at a constant flap setting with the gaps between the flap segments sealed. The model has been tested in the ARA 9ft by 8ft Transonic Wind Tunnel over the period 1985 - 1992 to investigate: (1) the effect of a canard, including variation in its position and setting angle; (2) the effect of alternative leading- and trailing-edge flap angles, including both positive and negative settings, although the model is capable of being tested with graded settings across the span (this option has not been investigated to date); (3) a three surface configuration (canard/wing/tailplane); and (4) a blended wing/body derivative of the model, using the existing outer wing and canard designs. Obviously these tests provide an extensive data base and the results included here comprise the datum wing without flap deflection, both with and without a canard. Author

N95-17877# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Entwurfsaerodynamik.
SUBSONIC FLOW AROUND US-ORBITER MODEL FALKE IN THE DNW
R. RADESPIEL and A. QUAST *In* AGARD, A selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 13 p (SEE N95-17846 04-02) Aug. 1994
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The contribution describes wind tunnel measurements of aerodynamic forces, pressure distributions and surface visualization for the FALKE model. FALKE is a model of the US-Orbiter in the scale 1:5.427. The test results taken in the subsonic wind tunnel DNW enable validation of computational methods for reentry vehicles in landing conditions at high Reynolds numbers, where strong vortical flow occurs on the upper side of the configuration. Author

N95-17878# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Entwurfsaerodynamik.
PRESSURE DISTRIBUTION MEASUREMENTS ON AN ISOLATED TPS 441 NACELLE
R. KIOCK and W. BAUMERT (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany.) *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 9 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A02/MF A06

The demand for even more economic jet engines requires extensive experimental investigations of the complete flow field around wing-body-engine-pylon (WBEP) configurations. The engine can be simulated best by pressure-driven devices, so-called Turbine-Powered Simulators (TPS). Though they have been applied for about 20 years, very few nacelle surface pressure measurements were carried out up to now. The reason is seen in the small size of the engine and in the poor theoretical capabilities in the past. Nowadays, WBEP configurations are handled by the Euler code, but experimental validation is required. One pre-step is the experimental investigation of the isolated nacelle which is presented here. Author

N95-17879*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SINGLE-ENGINE TAIL INTERFERENCE MODEL
BOBBY L. BERRIER *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 23 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

The data presented in this contribution were obtained in the NASA Langley 16-Foot Transonic Tunnel. Multiple test entries were completed and the results have been completely reported in five NASA reports. The objective of the initial investigation was to

determine the effect of empennage (tail) interference on the drag characteristics of an axisymmetric model with a single engine fighter aft-end with convergent divergent nozzles. Two nozzle power settings, dry and maximum afterburning, were investigated. Several empennage arrangements and afterbody modifications were investigated during the initial investigation. Subsequent investigations were used to determine the effects of other model variables including tail incidence, tail span, and nozzle shape. For the final investigation, extensive surface pressure instrumentation was added to the model in order to develop and understanding of the flow interactions associated with afterbody/empennage integration and also to provide data for code validation. Extensive computational analysis has been conducted on the staggered empennage configuration at a Mach number of 0.6 utilizing a three-dimensional Navier Stokes code. Most of the investigations were conducted at Mach numbers from 0.60 to 1.20 and at ratios of jet total pressure to free stream static pressure (nozzle pressure ratio) from 0.1 (jet off) to 8.0. Some angle of attack variation was obtained at jet off conditions. Author

N95-17880*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TWIN ENGINE AFTERBODY MODEL
DAVID J. WING *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 17 p (SEE N95-17846 04-02) Aug. 1994
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This test was originally conducted to determine the effects of several empennage and afterbody parameters on the aft-end aerodynamic characteristics of a twin-engine fighter-type configuration. Model variables were as follows: horizontal tail axial location and incidence, vertical tail axial location and configuration (twin-vs single-tail arrangements), tail booms, and nozzle power setting. Jet propulsion was simulated by exhausting high-pressure, cold-flow air from the nozzles. Following a successful test conducted on a single engine nacelle model to validate a CFD code, this model was chosen to be instrumented with pressure taps on the afterbody and nozzles and used as a follow-on test, providing a more complex geometry for the CFD code validation. A more limited test matrix was run to collect the pressure data, employing only the twin-tail configuration and varying only the horizontal and vertical tail locations. Mach number was varied from 0.6 to 1.2. Nozzle pressure ratio was varied from jet-off to 8. Angle-of-attack varied from 0 to 8 deg. Author

N95-17881*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
STOVL CFD MODEL TEST CASE
KARLIN R. ROTH *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 16 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

The transitional flight characteristics of a geometrically simplified Short Take-Off Vertical Landing (STOVL) aircraft configuration have been measured in the NASA Ames 7- by 10-Foot Wind Tunnel. The experiment is the first in a sequence of tests designed to provide detailed data for evaluating the capability of computational fluid dynamics methods to predict the important flow parameters for powered lift. The model consists of a 60 deg cropped delta wing platform, blended fuselage and two circular in-line jets that exit perpendicularly from the flat lower surface. The measured flows have a maximum freestream Mach number of 0.2. Model angle of attack is varied between -10 and +20 deg. The flow is ambient temperature in both jet exits and the nozzle pressure ratios are varied between 1 and 3. The data presented includes forces and moments, pressures measured at 281 surface pressure ports and the pressures of the jets. Measurements of the flow are also made in the tunnel test section upstream and downstream of the model and at the jet exits to guide boundary condition selection for the planned computations. Flow visualization and total pressure measurements in the jet plumes provide a description of the three-dimensional jet efflux flowfield. Author

N95-17882# Aeronautical Research Inst. of Sweden, Bromma. Flygtekniska Foersoeksanstalten.
LOW SPEED PROPELLER SLIPSTREAM AERODYNAMIC EFFECTS
I. SAMUELSSON *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 21 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

The data presented in this contribution to AGARD WG-14: 'EXPERIMENTAL TEST CASES FOR CFD VALIDATION' were obtained at tests in the FFA Low Speed Wind Tunnel LT1 (diameter 3.6 m) as part of an aeronautical research programme sponsored by the Swedish Board for Technical Development (STU). The intent of the experiment was two-fold: (1) to gain some physical insight to the complex aerodynamic interference phenomena occurring when the slip-stream from a highly loaded propeller washes downstream located surfaces (nacelle and wing); (2) to provide surface pressures and flow field data for evaluation of three-dimensional flow computation methods. The performed wind tunnel tests show that in high power conditions at low speeds large asymmetrical loads can develop on the nacelle and on the wing. For e.g. an aircraft with two propellers having the same sense of rotation these loads do not cancel out but combine to a net increase in asymmetrical loads (in particular side force and yawing moment). These effects, if not known or accounted for in advance, could lead to a resizing of the aircraft control surfaces and/or necessary trim changes with subsequent increased trim drag. Author

N95-17883# Maryland Univ., College Park, MD. Center for Rotorcraft Education and Research.
EXPERIMENTAL DATA ON THE AERODYNAMIC INTERACTIONS BETWEEN A HELICOPTER ROTOR AND AN AIRFRAME
J. G. LEISHMAN and NAI-PEI BI *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 17 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

The data presented in this contribution were obtained at the Center for Rotorcraft Education and Research at the University of Maryland under part of a research program sponsored by the United States Army Research Office. The experiments were performed in several wind-tunnel entries during the period from June 1988 through June 1990. The purpose of the experiments was to provide a better understanding into the origin of rotor/airframe interactional aerodynamic effects that are present on helicopters and other rotary wing aircraft. The measured results provide several unique and challenging engineering test cases for computational fluid dynamic methods used to model helicopter rotor wakes and rotor/airframe interaction phenomena. Author

N95-17884# Aircraft Research Association Ltd., Bedford (England).
INVESTIGATION INTO THE AERODYNAMIC CHARACTERISTICS OF A COMBAT AIRCRAFT RESEARCH MODEL FITTED WITH A FORWARD SWEPT WING
D. STANNILAND *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 26 p (SEE N95-17846 04-02) Aug. 1994
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The submission covers a series of tests on a combat aircraft research model fitted with a forward swept wing. The purpose of the tests was to investigate the flow development of the upper surface of the wing and to establish a level of confidence in the CFD methods used for the wing design. The fuselage was specified algebraically in order to permit a precise definition of the geometry both for CFD calculations and model manufacture, and the model was fitted with pressure tappings on the wing, fuselage and canard. The tests were performed in the ARA 9ft x 8ft Transonic Wind Tunnel in February 1985. Author

N95-17885# Aircraft Research Association Ltd., Bedford (England).
INVESTIGATION OF THE INFLUENCE OF PYLONS AND STORES ON THE WING LOWER SURFACE FLOW
D. STANNILAND *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 16 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

The submission describes a series of tests on a large half model with a constant chord, untwisted, constant section wing with 25 sweep. The aim of these tests was to investigate the influence of pylons and stores on the wing surface flow, particularly the development of shocks and separations around the pylons with an associated increase in drag. To this end a large number of surface pressure tappings were provided on the wing lower surface (17 stations), on the inboard and outboard sides of each of the pylons and around the mid-pylon store. Since these data were to be used primarily for the validation of CFD codes, for this class of configuration, the fuselage and store are precisely defined bodies of revolution which can be modelled easily by the CFD geometry packages. The tests were performed in the ARA 9ft x 8 ft Transonic Wind Tunnel in February 1986. Author

N95-18604# De Havilland Aircraft Co. of Canada Ltd., Downsview (Ontario).
A REVIEW OF GUST LOAD CALCULATION METHODS AT DE HAVILLAND
JOHN GLASER *In* AGARD, Aircraft Loads due to Turbulence and their Impact on Design and Certification 9 p (SEE N95-18597 05-08) Dec. 1994
(AGARD-R-798) Copyright Avail: CASI HC A02/MF A01

The development of an analysis system for the routine calculation of gust response loads is reviewed in some detail in this report. While the system provides adequate design strength margins, a more robust and effective system would reduce user workload, computer costs and analysis time. it is suggested that other analysis systems could benefit similarly, particularly when considering the demands imposed by highly nonlinear aircraft systems, the trend toward full finite element structural dynamic models and the relentless quest for structural efficiency. It is proposed that improvements in analysis systems could evolve from the collective experience in gust loads methodologies acquired within the aeronautical community. To capitalize on that collective experience, it is recommended that a working group of gust load specialists be formed to assemble and evaluate current and promising methods for calculating gust loads and to recommend standardized airplane test cases, both rigid and elastic, for validating analysis methods and results. Author

N95-19259# Technische Univ., Delft (Netherlands). High Speed Aerodynamics Lab.
THE UTILIZATION OF A HIGH SPEED REFLECTIVE VISUALIZATION SYSTEM IN THE STUDY OF TRANSONIC FLOW OVER A DELTA WING
S. R. DONOHOE and W. J. BANNINK *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 13 p (SEE N95-19251 05-34) Jul. 1994
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

An experimental study was conducted to examine the flow over a non-cambered 65 deg swept delta wing with a sharp leading edge in high subsonic compressible flow at various angles of attack. This flow is known to be highly three dimensional. At certain combinations of Mach number and high angle of attack, an unsteady and often non axial symmetric phenomenon known as vortex breakdown is found to occur above the wing. The present experimental study includes both visualizations of the flow over the model surface and of the flow field itself. The surface flow visualization study is done using a conventional oil-flow visualization technique. Flow field visualizations are done using both a traditional transmission visualization system as well as a newly developed Surface Reflective Visualization (SRV) technique. The development and application of this SRV system will be the main topic addressed in the current report. The SRV technique provides a new perspective on the compressible flow over wings. This technique incorporates a specially designed model with a reflective surface to enable visualization of the flow over the wing in plan view. The technique has been developed and applied to the transonic flow over a delta wing presently under investigation in a vortex breakdown research program. The plan view perspective makes it possible to visualize the span-wise distribution of the shock system present in the flow field and provides confirmation of the existence of cross flow shocks for certain combinations of Mach number and angle of attack. Combining this technique with the use of a high-speed camera enables the high speed shock fluctuations associated with this flow to be assessed for the first time. The SRV system, thus, allows insight to be gained into the time scales associated with these shock fluctuations and the vortex breakdown phenomenon in general. Author

N95-19260# British Aerospace Aircraft Group, Preston (England). Aerodynamics Dept.
TRANSONIC AND SUPERSONIC FLOWFIELD MEASUREMENTS ABOUT AXISYMMETRIC AFTERBODIES FOR VALIDATION OF ADVANCED CFD CODES
MARTIN BURT, PHILIP MILLER (Miller and Wilson Aerodynamics Research, Bath, England.), and JOHAN AGRELL (Aeronautical Research Inst. of Sweden, Bromma.) *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 28 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by Swedish Ministry of Defence
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

Two axisymmetric afterbody experimental programs, aimed at providing necessary and sufficient data for CFD code validation, were conducted in the FFA S5 suckdown wind-tunnel. Flow conditions covered the range of transonic to supersonic. Mean and fluctuating flowfield velocities in a single longitudinal plane were measured using LDA along many traverses, both over the afterbody and in the jet and mixing regions. Flow separated on the boattail of the AGARD 10 and 15 degree geometries at all conditions tested. Separation also occurred on a conical afterbody at supersonic Mach number. Comprehensive sets of boundary condition data were also recorded, through a wide variety of techniques. Extensive error analyses have been undertaken to evaluate the accuracy of all data. Transonic Navier-Stokes computations on the configurations were performed and showed the benefit of having static pressure information along the slotted tunnel roof. An algebraic stress model of turbulence returned predictions of afterbody surface pressures superior to two more simple models, in both attached and separated flow. Author

N95-19261# Technische Univ., Munich (Germany). Lehrstuhl fuer Fluidmechanik.
VELOCITY MEASUREMENTS WITH HOT-WIRES IN A VORTEX-DOMINATED FLOWFIELD
CHRISTIAN BREITSAMTER and BORIS LASCHKA *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 13 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by MBB Original contains color illustrations
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Selected results from a quantitative experimental investigation documenting the low-speed flow environment over a 75 deg swept delta wing and over a delta-canard-configuration are presented. The hot-wire measurement techniques using cross-wire and triple-wire probes are described. Results obtained include detailed flowfields of the time-dependent velocity components for angles of attack from 12.5 deg to 31.5 deg at a test Reynolds number of 1.0 x 10(exp 6). The structure of the highly turbulent vortex dominated flow is clearly shown by time-averaged, root-mean-square and spectral distributions. Thus the delta wing vortex substructure organized by discrete vortices and vortex breakdown characteristics are analyzed. With increasing incidence both the wing and the canard leading-edge vortices move inboard resulting in increase of the velocity fluctuations due to the bursting of these vortices. At the delta-canard configuration strong interference effects between the canard and the wing vortex systems are found. Peaked velocity spectra are detected in the vorticity sheets at burst flow conditions related to a narrow-band concentration of kinetic turbulent energy in the flow of the wing/canard vortex sheets. Author

N95-19268*# Georgia Inst. of Tech., Atlanta, GA. Aerospace Lab.

DEVELOPMENT OF PNEUMATIC TEST TECHNIQUES FOR SUBSONIC HIGH-LIFT AND IN-GROUND-EFFECT WIND TUNNEL INVESTIGATIONS

ROBERT J. ENGLAR *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 11 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by NASA. Langley Research Center

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Wind tunnel evaluations of two-dimensional high-lift airfoils and of vehicles operating in ground effect near the tunnel floor require special test facilities and procedures. These are needed to avoid errors caused by proximity to the walls and interference from the wall boundary layers. Pneumatic test techniques and facilities were developed for GTRI aerodynamic research tunnels and calibrated to verify that these wall effects had been removed. The modified facilities were then employed to evaluate the aerodynamic characteristics of blown very-high-lift airfoils and of racing hydroplanes operating in ground effect at various levels above the floor. The pneumatic facilities, techniques and calibrations are discussed and typical aerodynamic data recorded both with and without the test-section blowing systems are presented. Author

N95-19270*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

WALL INTERACTION EFFECTS FOR A FULL-SCALE HELICOPTER ROTOR IN THE NASA AMES 80- BY 120-FOOT WIND TUNNEL

PATRICK M. SHINODA *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 14 p (SEE N95-19251 05-34) Jul. 1994 Prepared in cooperation with Army Aviation Research and Development Command, Moffett Field, CA

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A full-scale helicopter rotor test was conducted in the NASA Ames 80- by 120-Foot Wind Tunnel with a four-bladed S-76 rotor system. This wind tunnel test generated a unique and extensive data base covering a wide range of rotor shaft angles-of-attack and rotor thrust conditions from 0 to 100 knots. Three configurations were tested: (1) empty tunnel; (2) test stand body (fuselage) and support system; and (3) fuselage and support system with rotor installed. Empty tunnel wall pressure data are evaluated as a function of tunnel speed to understand the baseline characteristics. Aerodynamic interaction effects between the fuselage and the walls of the tunnel are investigated by comparing wall, ceiling, and floor pressures for various tunnel velocities and fuselage angles-of-attack. Aerodynamic interaction effects between the rotor and the walls of the tunnel are also investigated by comparing wall, ceiling, and floor pressures for various rotor shaft angles, rotor thrust conditions, and tunnel velocities. Empty tunnel wall pressure data show good repeatability and are not affected by tunnel speed. In addition, the tunnel wall pressure profiles are not affected by the presence of the fuselage apart from a pressure shift. Results do not indicate that the tunnel wall pressure profiles are affected by the presence of the rotor. Significant changes in the wall, ceiling, and floor pressure profiles occur with changing tunnel speeds for constant rotor thrust and shaft angle conditions. Significant changes were also observed when varying rotor thrust or rotor shaft angle-of-attack. Other results indicate that dynamic rotor loads and blade motion are influenced by the presence of the tunnel walls at very low tunnel velocity and, together with the wall pressure data, provide a good indication of flow breakdown. Author

N95-19278# Institute for Aerospace Research, Ottawa (Ontario). High Speed Aerodynamics Lab.

EVALUATION OF COMBINED WALL- AND SUPPORT-INTERFERENCE ON WIND TUNNEL MODELS

M. MOKRY *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 11 p (SEE N95-19251 05-34) Jul. 1994

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Coupled interference effects of model support systems and ventilated test section walls on stream parameters at the model are calculated using a subsonic source panel method. The configurations discussed are the movable sting support system and the model plate mount in the IAR 1.5 m x 1.5 m perforated-wall wind tunnel, and an automobile model in the DSMA slotted-wall wind tunnel. Author

N95-19279# Aerospatiale, Toulouse (France).

INTERACTION OF A THREE STRUT SUPPORT ON THE AERODYNAMIC CHARACTERISTICS OF A CIVIL AVIATION MODEL [INTERACTION D'UN SUPPORT DE TYPE 3 MATS SUR LES CARACTERISTIQUES AERODYNAMIQUES D'UNE MAQUETTE D'AVION CIVIL]

J. WILLAUME, C. QUEMARD (Office National d'Etudes et de Recherches Aerospatiales, Toulouse, France.), and A. BONNET (Ecole Nationale Superieure de l'Aeronautique et de l'Espace, Toulouse, France.) *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 25 p (SEE N95-19251 05-34) Jul. 1994 In FRENCH

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The interference effects of a three strut support system on the longitudinal aerodynamic characteristics of a model is mainly due to the guards. Our purpose is to describe two theoretical methods allowing to gain access to the level of correction to apply to the wind tunnel gross measurements. The first one is a well known panel method which provides a global correction of the forces; the second one is a simplified method which calculates separately both the displacement effect (thickness) of the guards and the mutual lift effect between them and the wing. The validity of these theoretical results has been checked by specific tests in wind tunnel F1 (ONERA) on a model of the AIRBUS A310. The experimental interference due to the struts and the influence of the model on the strut tares are also discussed. Author

N95-19280# De Havilland Aircraft Co. of Canada Ltd., Downsview (Ontario). Aerodynamic Research and Development.

INTERFERENCE CORRECTIONS FOR A CENTRE-LINE PLATE MOUNT IN A POROUS-WALLED TRANSONIC WIND TUNNEL

RICHARD J. D. POOLE and ROBIN D. GALWAY (Institute for Aerospace Research, Ottawa, Ontario.) *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 10 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by Industry, Science and Technology Canada and Inst. for Aerospace Research

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A program of collaborative research between the National Research Council of Canada, Institute for Aerospace Research (IAR), and de Havilland Inc. included the design and manufacture of a slim center-line plate mount model support for installation in the IAR 1.5 m Trisonic Wind Tunnel. The primary objective of the collaborative research program was to provide a mounting method suitable for accurate measurement of the drag increments resulting from configuration changes on typical transport aircraft models. The secondary objective was to derive the tare effect of the model mounting plate so that datum aerodynamic parameters could be measured. To obtain the tare effect of the mounting plate on a model, an alternative mount from the tunnel ceiling was designed and built. The 'Y-Mount' allowed the model to be held in close proximity to a dummy plate and also to be tested without the plate in the tunnel. Comparative plate in and plate out measurements were made for a range of Mach numbers and model incidences to obtain the plate tares. Author

N95-19281# German-Dutch Wind Tunnel, North East Polder (Netherlands).

CORRECTION OF SUPPORT INFLUENCES ON MEASUREMENTS WITH STING MOUNTED WIND TUNNEL MODELS

D. ECKERT *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 11 p (SEE N95-19251 05-34) Jul. 1994

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The structures of wind tunnel model supports always penetrate the so-called near field of the flow around the model. Therefore, support corrections of aerodynamic coefficients, evaluated either by measurement or by calculation, depend on the specific configuration of the model and of the model/support intersection. As a consequence support influences known for the correction of a wind tunnel measurement with one model are, in general, not transferrable to another configuration. Nevertheless, such a generalization, at least between models of the same aircraft family, would in principle be very helpful in avoiding the time consuming

measurements or the viscous flow calculations necessary for the evaluation of support corrections. To this end, at DNW a comprehensive data-base of measured influences of three sting support types on different low-speed aircraft models was analyzed. The aim was to split up the total support effects in terms representing the effect of support volumes located in the far field of the model and in terms representing the effect of support elements located in the near field of the model. The data-base has been analyzed with the aid of a physical model which interprets support influences as flow perturbations relevant for the wing, the fuselage, and the tail of the model. This analysis showed that for some fuselage/sting arrangements the near field effects may be considered small compared with the far field effects and independent of the wing's slat/flap configuration. These findings offered the important possibility of using near field dependent correction terms known for one model configuration for measurements with new configurations (e.g. new wing slat/flap combination). In order to determine the far field influence on new configurations, the physical model mentioned before is used in DNW's on-line data processing system to calculate the support corrections by combining previously determined flow perturbations with the actual measurements during routine tests. Examples show the successful application of the method to measurements with different models. Author

N95-19282# Analytical Methods, Inc., Redmond, WA.
CALCULATION OF SUPPORT INTERFERENCE IN DYNAMIC WIND-TUNNEL TESTS
D. ALMOSNINO *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 6 p (SEE N95-19251 05-34) Jul. 1994
(AGARD-CP-535) Copyright Avail: CASI HC A02/MF A04

An unsteady, subsonic flow panel method is applied to predict the support interference effects in dynamic wind tunnel test simulation. Interference effects are calculated by simulating the unsteady flow around the aircraft model, both in the presence and absence of the support system, unlike common experimental techniques that try to measure these effects. The present study uses the standard dynamics model (SDM) in pitch oscillations as a test case. Calculated results for free flight conditions are compared with results obtained when simulating the presence of an existing side-wall-mounted support system in a dynamic wind-tunnel test facility. The calculated results are also compared with experimental data available from different dynamic wind tunnel test facilities. Author

03

AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

N92-28530# Naval Air Test Center, Patuxent River, MD. Strike Aircraft Test Directorate.
USE OF HIGH-FIDELITY SIMULATION IN THE DEVELOPMENT OF AN F/A-18 ACTIVE GROUND COLLISION AVOIDANCE SYSTEM
TIMOTHY R. FITZGERALD and MICHAEL T. BRUNNER *In* AGARD, Piloted Simulation Effectiveness 13 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

An active Ground Collision Avoidance System (GCAS) was developed for the F/A-18 using the Naval Air Test Center's F/A-18 simulation. The simulation was used for the development of all three components of GCAS: (1) the algorithms used to determine the recovery initiation altitude; (2) the additional flight control laws (FCL's) necessary to perform the recovery maneuver; and (3) the visual and audio cues used to provide recovery status information to the pilot. The use of a simulation has allowed the rapid development of a viable F/A-18 GCAS that incorporates technology from the F/A-18 Integrated Fire and Flight Control (IFFC) simulation and the Advanced Fighter Technology Integration (AFTI) F-16 program. Complete system development and preliminary evaluations were performed using the simulation. This increased overall project safety while decreasing development and potential flight test costs significantly. Author

N93-19653# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
AIRCRAFT ACCIDENTS: TRENDS IN AEROSPACE MEDICAL INVESTIGATION TECHNIQUES [LES ACCIDENTS D'AERONEFS: LES TENDANCES EN TECHNIQUES D'INVESTIGATION MEDICALE]
Sep. 1992 452 p In ENGLISH and FRENCH Symposium held in Cesme, Turkey, 27 Apr. - 1 May 1992
(AGARD-CP-532; ISBN-92-835-0687-1) Copyright Avail: CASI HC A20/MF A04

These proceedings include the Technical Evaluation Report and 58 papers of the Symposium sponsored by the AGARD Aerospace Medical Panel held at the Altin Yunus Hotel, Cesme, Turkey, April 27 - May1 , 1992. Since the commencement of aviation, accidents have occurred for a variety of reasons in both fixed- and rotary-wing aircraft. As the complexity of aviation systems increased, so did the task of investigating aircraft accidents. At the same time, advanced techniques in aviation and weapon systems have exacerbated greatly the physiological and cognitive demands on aircrews. The result is that aircraft accidents due to material causes have diminished progressively while the percentage of human factor-caused accidents has not. For individual titles, see N93-19654 through N93-19710.

N93-19654# Army Personnel Research Establishment, Farnborough (England).
HUMAN FACTORS IN AIRCRAFT ACCIDENT INVESTIGATION
ROGER GREEN *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 4 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

An opening speech of the meeting is addressed. Two brief basic psychological effects that can cause both pilots and accident investigators to err are discussed. The first is one of the most important psychological causes of human error accidents, and is the family of effects sometimes referred to as 'hypothesis locking' or 'confirmation bias'. The second effect, or set of effects, concerns the social factors that influence crew behavior on flight decks, and the example from the database of the UK Confidential Human Factors Incident Reporting Programme (CHIRP). I.I.C.

N93-19655# Swedish Air Force, Stockholm (Sweden).
HOW DO WE INVESTIGATE THE HUMAN FACTOR IN AIRCRAFT ACCIDENTS?
KRISTINA POLLACK *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 3 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

Today, the reality is that two-thirds of accidents and incidents are related to Human Factors. The concept of Human Factors is hard to define, identify or verify and definitions of the concept are as many as its advocates. In order to be aware of the complexity of the Human Factor in defining the root cause of an accident, to sub-categorize the concept, to be able to analyze and to see the trends over a period of time, trained experts are required. The findings, including the Human Factor findings, must influence the total report, which will form the basis of future flight safety work. I.I.C.

N93-19656# Norton AFB Ballistic Missile Office, CA.
A METHOD FOR INVESTIGATING HUMAN FACTOR ASPECTS OF MILITARY AIRCRAFT ACCIDENTS
RICHARD A. LEVY *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 19 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A03/MF A04

The term 'human factor' denotes the relationship between the aviator, the aircraft and the environment. This covers a very large and complex interrelated panorama of factors, to include as an example, personal stress, training, physiology, aircraft flight characteristics, judgement and decision making, experience, nutrition, fatigue, and motivation. A major concern in assessing the significance of any particular human factor, or combination of factors, is the method employed in the collection of the raw data

and subsequent analysis. The method of investigation and analysis employed by the U.S. Air Force, the problems inherent in this approach, and a joint, NATO human factors aircraft accident investigation methodology and program are discussed. I.I.C.

N93-19657# Canadian Forces Headquarters, Ottawa (Ontario).
THE HUMAN FACTOR PROBLEM IN THE CANADIAN FORCES AVIATION
J. F. DAVID *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 9 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

A 10-year analysis of human factor errors in the Canadian Air Force and where efforts should be concentrated to reduce human error are discussed. A 10-year analysis of our ground accidents and interestingly, close to 84 percent of the causes were related to personnel errors. Although the overall supervisory error was approximately 10 percent, it represented only 6 percent of the personnel error in air occurrences and close to 19 percent in ground occurrences. It was concluded that aviation psychology needs more investment. Furthermore, we cannot progress effectively in this area unless an extensive human factor data base is developed over coming decades. A human factor data base will allow for meaningful and more objective assessment by the decision makers and leaders. I.I.C.

N93-19658# Royal Netherlands Air Force, The Hague (Netherlands).
UNDERLYING CAUSES OF ACCIDENTS: CASUAL NETWORKS
FERDINAND H. J. I. RAMECKERS *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 4 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

This paper describes recent thinking about Accident Causation Theory, accident investigation and accident prevention. The central notion is that human error as the primary cause of accident causation, prevails at all levels in any complex organization and that accidents are caused by a unique network of factors, generated not only by unsafe acts of front-line operators, but also by fallible management decisions and all kinds of (psychological) preconditions that exist in the operations environment. New approaches aiming at possibilities of proactive prevention are briefly touched. Author

N93-19659# Dassault Aviation, Istres (France).
AID IN INVESTIGATION BY FIGURE ANIMATION [AIDE A L'ENQUETE PAR FIGURATION ANIMEE]
JEAN COUREAU *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 11 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH
(AGARD-CP-532) Copyright Avail: CASI HC A03/MF A04

The investigation into the causes of accidents is an increasingly difficult undertaking because the human factors become largely prevalent in more than 75 percent of cases and everyone knows that they are delicate to interpret. Moreover the hardware is more and more comprised of electronics and software, so that the physical traces are often non-existent, outside of the parameters recorded on the 'crash recorder' and CVR. At the time of the analysis of the listings or layouts, the independent or little correlated parameters are interpreted easily, such as the driving mode and temperature. On the other hand, the quickly evolving and highly correlated parameters are harder to approach: the response of an aircraft to longitudinal and transverse stresses combined, for example. Software allowing the presentation on a graphic console of the parameters recorded from the pilot's viewpoint and animated in real time has been developed on the basis of a test by Dassault Aviation in Istres. The result satisfies all hopes: it is possible to view the flight at normal speed, at idle, accelerated, or to stop an image. The instrument panel is similar to that of the aircraft, the lever and the handle move as in reality. The horizon of the landscapes gives paravisual information of the movements of the aircraft. The investigators really 'feel' the way in which the pilot reacted to the movements of the aircraft or the events which occurred: signs of carelessness, nervousness or even a change of pilot at the controls on a two-seater. In another presentation, a model seen from the outside reproduces the movements of the aircraft for complex trend analysis: spins, stalls, etc. Finally layouts, with or without zoom, give the evolution of the desired parameters in analog, as on paper, but with more flexibility of use. A video film presenting some typical flight cases is intended to emphasize the advantages of this kind of animation. A description of the operations of data acquisition of a military aircraft is given. A flow chart of the software for presentation on a graphic console is provided. Author

N93-19661# Department of Transport (England). Air Accidents Investigation Branch.
737-400 AT KEGWORTH, 8 JANUARY 1989: THE AAIB INVESTIGATION
R. D. G. CARTER *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 15 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A03/MF A04

A Boeing 737-400, jet transport aircraft, G-OBME, carrying 8 crew and 118 passengers, crashed near Kegworth, Leicestershire, on 8th January 1989. Of the 126 occupants, 47 died as a result of the accident and a further 74 suffered serious injury. This paper describes the structures and survivability investigations conducted into this accident by the Air Accidents Investigation Branch (AAIB) of the UK Department of Transport and reproduces the 11 AAIB Safety Recommendations (out of a total of 31 in the final report) concerning crashworthiness and survivability. This paper also describes the study performed for this investigation by the Cranfield Impact Centre, using the KRASH computer code to quantify impact pulses. The results of the KRASH work supported the AAIB recommendations in the G-OBME report and form the background to a program at the Cranfield Impact Centre to facilitate the use of impact computer codes in aircraft accident investigations. Author

N93-19673# Air Force Wright Aeronautical Labs., Langley AFB, VA. Aerospace Medicine Div.
HUMAN FACTORS CAUSES AND MANAGEMENT STRATEGIES IN US AIR FORCE F-16 MISHAPS 1984-PRESENT
R. D. VANDERBEEK *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 5 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

The F-16 was introduced into the US Air Force in 1975 as the YF-16. It began significant operational employment in the early 1980's. For this paper statistics reflect mishaps since 1984, an arbitrary starting point reflecting mature operational F-16 employment as the venerable F-4 was being phased into retirement. A review of all F-16 Class 'A' mishaps (i.e. loss of aircraft, life, or damage exceeding $1 million) from January 1984 through the end of March 1992 is presented. These mishaps are first listed within traditional causal categories. The mishaps where operator factor was cited are then recategorized into an expanded umbrella framework reflecting operationally meaningful subsets of situational awareness (SA). This SA framework more clearly demonstrates the role and importance of pilot attention and broader awareness in mishap avoidance. A program developed by Tactical Air Command, United States Air Force, to improve pilot attention and awareness is then discussed. Author

N93-19674# Royal Norwegian Air Force, Blindern (Norway).
F-16 ACCIDENTS: THE NORWEGIAN EXPERIENCE
SUZANNE KLAVENESS and HARALD T. ANDERSEN *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 3 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

Investigation reports from F-16 mishaps in the Royal Norwegian Air Force have been studied. In order to evaluate and improve the human factor information contained in the written records of F-16 mishaps, we have examined all information available in the Royal Norwegian Air Force for a ten year period, 1981 to 1990. Author

N93-19675# Belgian Air Force, Beauvechain (Belgium).
CATEGORY A F-16 ACCIDENTS IN THE BELGIAN AIR FORCE [LES ACCIDENTS F-16 DE CATEGORIE A A LA FORCE AERIENNE BELGE]
R. DELHAYE and P. VANDENBOSCH *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 3 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH
(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

The Belgian Air Forces have been flying on F-16's since 1979; a review of all the class A mishaps is realized. This global study points out a particular human factor that could not be found in a single analysis of each mishap. Author

N93-19676# Centre d'Essais en Vol, Bretigny-Air (France).
AIR ACCIDENTS IN THE FRENCH AIR FORCE [ACCIDENTS AERIENS DANS L'ARMEE DE L'AIR FRANCAISE (1977-1990): INFLUENCE DES AERONEFS DE LA NOUVELLE GENERATION]
G. OSSARD, H. MAROTTE, J. M. CLERE, and J. Y. GRAU *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 10 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

This assessment of the air accidents in the French Air Force covered the period 1977-1990. During this period, combat aircraft of the new generation were brought into service without an important variation of the number of air accidents being observed, although the rate of accidents per 10,000 hours of flight appears higher for new aircraft. The human factor remains the main cause of the air accidents in the combat category, but seems to be implied with less frequency with aircraft of the new generation. Mortality during combat accidents has tended to decrease regularly since 1987. Author

N93-19677# Belgian Air Force, Brussels (Belgium).
COMBAT AND TRAINING AIRCRAFT CLASS A MISHAPS IN THE BELGIAN AIR FORCE 1970-1990
I. BIESEMANS and P. VANDENBOSCH *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 12 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A03/MF A04

The authors reviewed the files of 114 combat and training aircraft class A mishaps in the Belgian Air Force during the period from 1970-1990 with the cooperation of the office of the 'Belgian Accident Investigation Board'. They searched for the causes of these accidents i.e. Operational related, Logistics related and environmental factors, as well as contributory factors which played a role in these mishaps. While considering the causes of these accidents, they found that 71 percent were operational related, 22 percent logistics related and 7 percent were caused by environmental factors, such as birdstrike, foreign object damage (FOD) to the engine and unknown. From the 23 training aircraft lost, only one single aircraft crash was caused by a technical failure. The overall attrition rate for the period was 1.08/10.000 Aircraft Hours (A/C) hours, being 1.43/10.000 for combat A/C and 0.55/10.000 for training A/C. The introduction of the agile F-16 fighter in the early 1980's, coinciding with a serious decrease of the annual flying time and an undermanning in terms of experienced pilots in the squadrons was most probably responsible for the negative trend in the evolution of the annual attrition rate until 1989. Although the Belgian Air Force remained two years without a major accident, it must resolutely continue its effort in the field of accident prevention. By extending the time spent by aircrews in an operational squadron, supervised by experienced pilots, the Belgian Air Force should be able to reduce class A mishaps in the future. Author

N93-19678# Army Safety Center, Fort Rucker, AL.
UNDERLYING CAUSES OF HUMAN ERROR IN US ARMY ROTARY WIND ACCIDENTS
DANIEL T. FITZPATRICK *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 6 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

Human error has been a causal factor in 80 percent of U.S. Army aviation accidents. The focus of an accident investigation is to identify the task errors and related system inadequacies that contributed to the accident occurrence. Within the U.S. Army, crew error aviation accidents have been attributed to one of five reasons: individual failure (41 percent), leader failure (27 percent), standards failure (15 percent), training failure (12 percent), or other failure (5 percent). This study describes the most frequently occurring aircrew task errors and associated problem areas causing U.S. Army rotary wing accidents from FY-84 through FY-91. A total of 554 accidents occurred, resulting from 906 aircrew errors. The three most frequently occurring task errors involved improper decision, improper attention, and inadequate communication. Together, they accounted for one half of the total number of identified errors. The most frequently reported problem areas were inadequate crew coordination and improper scanning, which accounted for almost 40 percent of the errors. There were minor differences noted for problem areas based on aircraft type, time of occurrence, and responsible aircrew member. The U.S. Army Aviation Center has introduced corrective measures that address these problem areas. If successful, these corrective measures should reduce crew error, resulting in fewer accidents and a savings in personnel and equipment. Author

N93-19684# Naval Aviation HQ, Yeovil (England).
ROYAL NAVAL HELICOPTER DITCHING EXPERIENCE
A. P. STEELE-PERKINS, R. P. JOHNSTON (Royal Naval Air Medical School, Hillhead , England), and P. BARTON (Royal Naval Air Medical School, Hillhead , England) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 6 p (SEE N93-19653 06-03) . Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

Controlled or uncontrolled water entry (ditching) by Royal Naval helicopters continues to occur and is a significant loss of resource - both human and aircraft. Accidents over a ten year period (1982-1991) are listed, causation and trends analyzed, and preventative measures put forward, as are initiatives to increase post ditching survivability. Author

N93-19685# Defence and Civil Inst. of Environmental Medicine, North York (Ontario).
CANADIAN FORCES HELICOPTER DITCHINGS: 1952-1990
C. J. BROOKS *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 12 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A03/MF A04

In 1982, Brooks and Rowe completed a 20 year retrospective review of the survival of all Canadian Military aircrew from ditching, parachuting or ejecting into both fresh and sea water, including the penetration of ice on frozen rivers and lakes. For the purpose of that study, all of these mishaps were classified as water accidents. The authors originally had intended to examine all water accidents back to 1952, but due to integration of the services and coincidental amalgamation of the RCAF Institute of Aviation Medicine and the Defence and Civil Institute of Environmental Medicine data prior to 1962 appeared to have been lost or destroyed. This paper summarizes the Canadian Military experience with ditching helicopters into water over the last 38 years. I.I.C.

N93-19686# Institut de Medicine Navale, Toulon-Naval (France).
HELICOPTER ACCIDENTS OVER WATER IN THE NATIONAL NAVY: EPIDEMIOLOGICAL STUDY OVER THE PERIOD 1980-1991 [ACCIDENTS D'HELICOPTERE AU DESSUS DE L'EAU DANS LA MARINE NATIONALE: ETUDE EPIDEMIOLOGIQUE SUR LA PERIODE 1980-1991]
PIERRE GIRY, PIERRE COURCOUX (Conseil Permanent de la Securite Arienne de la Marine, Paris, France), and JEAN PIERRE TAILLEMITE (Aeronautique Navale, Toulon-Naval, France) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH
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During the years 1980-1991, 11 French Navy helicopters ditched in the sea: 3 Super-Frelon, 3 LYNX-WG13, 3 Alouette 3, and 2 Alouette 2, 10 of them being equipped with flottability devices. Structure default was the identified cause of the accident in 2 cases, engine failure in 5 accidents, human error in 5 issues, the last one being unknown. Three accidents occurred at night, the 8 others during day-time. 54 persons (34 crew, 20 passengers) have been involved. The outcome has been: 19 dead or disappeared, 4 wounded and 31 uninjured. The aircraft capsized in 8 out of 11

occurrences, almost immediately after ditching in 6 cases, after a delay long enough for all the crew to escape in 2 cases. In one of these last occurrences, all the crew but 1 survivor (13 people) died (probably from cold exposure). In the other one (ditching in shallow warm waters, close to shore) no casualty occurred (10 safe). Escape problems have been reported in 2 accidents (5 people involved), leading to 3 casualties and 1 injured. Localization of survivors has been a major problem in 1 accident (visibility was so poor that only sound signals could be efficient). Author

N93-19687# Naval Air Station, Norfolk, VA. United States Naval Safety Center.

HELICOPTER CRASH SURVIVAL AT SEA: UNITED STATES NAVY/MARINE CORPS EXPERIENCE 1977-1990

C. O. BARKER, D. W. YACAVONE, M. S. BOROWSKY, and D. W. WILLIAMSON *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

This paper examines the United States Navy/Marine Corps' (USN) experience with helicopter Class A over water mishaps for the period from 1977 to 1990. There were 137 helicopter Class A flight mishaps over water during this period with an overall survival rate of 83 percent in survivable water crashes. During this period, the USN developed several programs to improve survivability. The helicopter water survival training device (WSTD or 9-D-5 device) was instituted in 1982. The helicopter emergency escape device system (HEEDS) and the helicopter emergency lighting system (HEELS) were implemented in 1987. This study attempts to answer the question whether or not these programs have, in fact, improved survival since their implementation. In addition, the study reviews the types of operational problems encountered with these devices. The results indicate that the WSTD and HEEDS may have contributed to the statistically significant improved survival seen among Navy aircrew in night crashes. They may have also contributed to the improvement (not statistically significant) in survival among passengers in night crashes. The data were inconclusive with respect to the effects of HEELS because of its not being implemented throughout the fleet. Operational problems with these devices were minor and the benefits of each program far outweigh any risks. In fact, in night crashes aircrew had significantly higher likelihood of survival than passengers who were essentially untrained occupants. Other factors, in addition to the devices studied, may have also affected survival probabilities. Author

N93-19688# Army Aeromedical Research Lab., Fort Rucker, AL. Biodynamics Research Div.

CRASH EXPERIENCE OF THE US ARMY BLACK HAWK HELICOPTER

DENNIS F. SHANAHAN *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 9 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

The U.S. Army UH-60A, Black Hawk, helicopter is the first helicopter designed and built to modern crashworthiness standards. During the design of the Black Hawk, all common injury mechanisms were considered, and significant attempts were made to eliminate foreseeable injury hazards. Most important, the aircraft was designed to withstand an 11.6 m/s (38 ft/s) vertical impact without acceleration injury to the occupants or collapse of structure or high mass items into occupied space. Crew and passengers were provided energy attenuating seats and state-of-the-art restraint systems. Head strike zones were considered and potentially injurious objects excluded from these zones. Additionally, the helicopter was equipped with an advanced crash resistant fuel system. First fielded in 1979, the Black Hawk now has accumulated over 1.1 million hours of flight time. Over the 11-year period from 1 October 1979 to 30 September 1990, there have been 75 class A and B mishaps of the UH-60 resulting in 84 fatalities and 121 personnel injured. Systematic analysis of these crashes has accumulated adequate data to assess the effectiveness of the crashworthiness features of the Black Hawk. The Black Hawk has proven itself to be highly crash survivable even in impacts up to 18.3 m/s (60 ft/s) vertical velocity. Most notable have been its structural integrity, tie-down strength of seats and restraint systems, effectiveness of energy absorbing seats and landing gear, effectiveness of the crash resistant fuel system, and retention of high mass items. Mitigating against this has been a higher than predicted accident rate, a markedly increased vertical velocity at impact compared to most other helicopters in use by the U.S. Army, and a tendency for the roof to collapse in high vertical velocity crashes. Author

N93-19689# Army Aeromedical Research Lab., Fort Rucker, AL. Biodynamics Research Div.

US ARMY HELICOPTER INERTIA REEL LOCKING FAILURES

B. JOSEPH MCENTIRE *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 6 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

The inertia reels utilized in U.S. Army helicopters are regulated by MIL-R-8236. This is a performance specification which requires the MA-6 and MA-8 inertia reels to automatically lock when the restraint strap is subjected to an acceleration between 1.5 and 3 G. A review of U.S. Army Safety Center, Fort Rucker, Alabama, mishap data revealed a number of critical and fatal injuries attributed to upper torso flailing that occur in survivable mishaps. Some of these injuries relate directly to the inertia reel either failing to lock or not automatically locking soon enough. Laboratory sled tests have revealed sporadic failures of the inertia reel in both its auto lock and manual lock positions. Inertia reel failures during high horizontal impacts are believed to be due to high rotational velocities of the ratchet wheel which may prevent the locking pawl from properly engaging the sprocket. Inertia reel failures during high vertical impacts are believed to be caused by the low forward acceleration (G(sub x)) transmitted to the shoulder strap because of torso compression, rolling, and slumping. The lack of inertia reel maintenance and calibration procedures potentially allow the automatic lock sensitivity settings to drift to unacceptable levels over time. The influence of operational conditions (i.e., sand, dust, salt fog, temperature, humidity, etc.) on sensitivity settings are unknown. Field tests of 110 inertia reels at Fort Rucker, Alabama, airfields revealed a 24.5 percent failure to lock at the 3 G requirements. Corrective actions being considered include: (1) establishing calibration and maintenance procedures, (2) revising MIL-R-8236 to incorporate dynamic sled tests and (3) development of an inflatable body and head restraint system. Author

N93-19690# Army Aeromedical Research Lab., Fort Rucker, AL. Biodynamics Research Div.

US ARMY'S AVIATION LIFE SUPPORT EQUIPMENT RETRIEVAL PROGRAM REAL WORLD DESIGN SUCCESSES FROM PROACTIVE INVESTIGATION

JOSEPH R. LICINA and ARTHUR C. SIPPO (Ohio National Guard, Columbus.) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 7 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

The U.S. Army Aeromedical Research Laboratory (USAARL) manages the Aviation Life Support Retrieval Program (ALSERP). The purpose of this program is to evaluate and record the efficiency of Aviation Life Support Equipment (ALSE) in the aircraft accident environment with our focus centered on rotary-wing aviation. Personal injury data are correlated with the item of ALSE provided for protection, along with information on the accident kinematics and dynamics. These ALSE items are assessed for damage to determine if the design was adequate, it was manufactured to design, and/or it was properly worn by the crewmember. These data are used by USAARL to identify design deficiencies and to substantiate the need for system improvements. The ALSE sent to USAARL for analysis includes: helmets, crashworthy seats, restraint systems, inertia reels, survival vests, and flight suites from the U.S. Army, and upon request, the Navy, Air Force, Coast Guard, and other government agencies. The primary item of equipment received by USAARL for analysis remains the helmet due to the identified criticality of head trauma in aviation mishaps. Author

N93-19691# Army Aeromedical Research Lab., Fort Rucker, AL.

THE EFFECTIVENESS OF AIRBAGS IN REDUCING THE SEVERITY OF HEAD INJURY FROM GUNSIGHT STRIKES IN ATTACK HELICOPTERS

NABIH M. ALEM, DENNIS F. SHANAHAN, JOHN V. BARSON, and WILLIAM H. MUZZY, III (Naval Biodynamics Lab., New Orleans, LA.) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 9 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

Accident investigation records at the U.S. Army Safety Center were examined to determine the frequency of gunner injuries incurred from striking the optical sighting systems in the Cobra and Apache attack helicopters during survivable mishaps. Among 105 survivable Cobra crashes during 1972-1990, the sighting system was implicated in 9 minor and 5 major injury cases, and 6 fatalities. The Apache had eight survivable mishaps since 1985, with only one gunner fatality which was attributed to the optical relay tube (ORT). In this Apache mishap and in the 11 Cobra cases where major or fatal injuries occurred, we theorized an airbag would have prevented serious injuries. To explore the role of airbags in reducing the severity of head strikes, we conducted 32 sled tests with and without airbags. In all tests without airbags, head strikes of the test manikin were sufficiently severe to cause facial fractures, but not necessarily irreversible brain damage. Airbags proved effective in reducing the severity of head strikes against sighting systems. Using mean values of several indicators of injury severity, airbags reduced head accelerations by 65 percent, head injury criteria by 77 percent, and head angular acceleration peal-to-peak swings by 76 percent in the Cobra tests. In the Apache tests, the airbags reduced those same indicators by 68, 52, and 83 percent, respectively. The study concludes that an airbag system, specifically designed for the Apache or Cobra, likely would prevent severe or fatal head and chest injuries. Author

N93-19692*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA. Aeroflight Dynamics Directorate.

PRE-FLIGHT RISK ASSESSMENT IN EMERGENCY MEDICAL SERVICE (EMS) HELICOPTERS

R. J. SHIVELY *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 4 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

The Emergency Medical Service (EMS) industry has been the subject of several television and newspaper articles (Harvey and Jensen, 1987) which emphasized the negative aspects, (e.g., fatalities and high accident rates), rather than the life saving services performed. Until recently, the accident rate of the EMS industry has been five times as high as that of other civil helicopters. This high accident rate has been coupled with the dramatic rise in the number of programs. The industry has built from a single service at its inception in 1972, to over 180 in 1987 (Spray, 1987), to the point that 93 percent of the contiguous U.S. is now covered by some type of EMS service. These factors prompted the National Transportation Safety Board (NTSB) to study the accidents that occurred between May 11, 1978 and December 3, 1986 (NTSB, 1988). The NTSB report concluded that 'Sound pilot judgment is central to safe flight operations.' They further stated that '... factors unique to EMS helicopter operations--such as the influence of the mission itself, program competition, and EMS program management perspectives--can drastically influence pilot judgment during the EMS mission.' One of the most difficult decisions that a pilot must make is whether to accept or decline a mission. A pre-flight risk assessment system (SAFE) was developed at NASA-Ames Research Center for civil EMS operations to aid pilots in making this decision objectively. The ability of the SAFE system to predict mission risk profiles was tested at an EMS facility. The results of this field study demonstrated that the usefulness of SAFE was highly dependent on the type of mission flown. SAFE is now being modified so that it can 'learn' with each mission flown. For example, after flying a mission to a particular site, an EMS pilot would input information about this mission into the system, such as new buildings, wires, or approach procedures. Then, the next time a pilot flew a similar mission or one to the same area, this additional information would be taken into account in computing a risk assessment. Author

N93-19693# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Berlin (Germany).

CORRELATIONS BETWEEN ENGINEERING, MEDICAL AND BEHAVIOURAL ASPECTS IN FIRE-RELATED AIRCRAFT ACCIDENTS

G. WINTERFELD *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 6 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

An overview is given over the present situation in aircraft fire safety as it can be derived from the 73rd AGARD-PEP-Meeting devoted to this subject in 1989. It is characterized by increasing interaction between engineering and medical/behavioral aspects. A scenario for aircraft cabin fires is first developed showing that survival times both from the technical and medical point of view are of the same order of magnitude. Although fire-hardening has contributed much to increased survival times the prospects for further progress from this side diminish. Improvements are expected from improved conditions for emergency evacuations and from occupant protection systems. Modeling studies both on engineering and medical problems are increasingly applied to fire-related problems. The use of water spray systems and smoke hoods are discussed in the paper as well as studies on passenger behavior during evacuations. The combination of medical, behavioral and engineering expertise can be used to promote and optimize passenger protection in fire-related aircraft accidents. Author

N93-19700# Army Personnel Research Establishment, Farnborough (England).

TOWARDS AN INTEGRATED APPROACH TO PROACTIVE MONITORING AND ACCIDENT PREVENTION

MICHAEL H. REJMAN, COLIN J. SYMONDS (City of London Polytechnic, England), and ERIC W. SHEPHERD (City of London Polytechnic, England) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 5 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

Most traditional accident prevention programmes are based on information learned from accident research. While acknowledging the contribution from this approach, two difficulties can be identified. First, many accidents may be the product of a unique combination of circumstances. Second, the whole process is 'reactive'. In contrast, the research initiative reported here begins with the premise that the components of any organization may already hold much information which could be relevant to safety research and which could be used 'proactively'. A novel feature of the methodology outlines in this programme is that each of the areas can be considered as stand-alone models, capable of providing useful management information in their own right. Taken together, they represent a powerful and integrated approach to an organization's flight safety and accident prevention programme. I.I.C.

N93-19701# Army Personnel Research Establishment, Farnborough (England).

ACCIDENTS AND ERRORS: A REVIEW OF RECENT UK ARMY AIR CORPS ACCIDENTS

MICHAEL H. REJMAN and COLIN J. SYMONDS (City of London Polytechnic, England) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 7 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

Aircraft accidents can be categorized in a number of different ways (e.g. aircraft type, amount of damage, nature and severity of injuries sustained). Similarly, causation can be attributed to a variety of different factors (e.g. aircrew error, technical failure, operational hazard). Of all the labels used in such schemes, the one which consistently dominates the list of causes is that referred to as 'human error'. In this respect the accident statistics of the UK Army Air Corps (AAC) are no exception. However a label such as 'human error' is not particularly enlightening with regard to accident aetiology, nor does it immediately suggest obvious areas for remedial action. To satisfy these requirements, more detailed categorization schemes are necessary. Three such schemes were applied to a sample of recent AAC accidents for which human factors investigations were available. Two of the schemes had been developed within the field of aviation accident investigation while the third represented recent development within cognitive

psychology. To date, around half of the accidents held in the database have been subjected to analysis. Preliminary results suggest that while all the schemes were useful, one particular scheme was easier to implement than the other two, provided a good understanding, and indicated areas for remedial action. The exercise is being extended to cover a larger sample. Author

N93-19702# City of London Polytechnic (England).
PREDICTION OF SUCCESS FROM TRAINING
COLIN J. SYMONDS, MICHAEL H. REJMAN (Army Personnel Research Establishment, Farnborough, England), and ERIC W. SHEPHERD *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04
Any training system contains information on the past and current performance of its students. However, such systems may also hold predictors capable of estimating the potential of a student. Failures that occur late during a course result in wasted costs, time and places, and also student career discontent. Therefore identifying the earliest indicators of failure is of primary importance to the operation of an efficient system. Research directed at uncovering these involves the identification of relevant behaviors; classification of the students' behaviors in real life situations; coding the classifications to form data points; and the application of analytic techniques to produce predictive models of behavior. The major emphasis of this paper is to describe attempts to define statistically derived criteria for success and failure in an existing flying training system. It is argued that the introduction of more objective techniques such as those described here may not only make the training system more efficient but may also reduce flight safety risks. Author

N93-21187# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
MISSION PLANNING SYSTEMS FOR TACTICAL AIRCRAFT (PRE-FLIGHT AND IN-FLIGHT) [SYSTEMES DE PLANIFICATION DES MISSIONS POUR AVIONS TACTIQUES (AVANT VOL ET EN VOL)]
Dec. 1992 62 p
(AGARD-AR-313; ISBN-92-835-0697-9) Copyright Avail: CASI HC A04/MF A01
AGARD Joint-Working Group 15 was established to review mission planning systems and to consider how they are likely to evolve in the future. Its terms of reference specified a program of two phases and the work carried out in the first of these was previously published as AGARD Advisory Report 296. This report covers the work of phase 2. The principle objective of the phase 2 studies was to investigate in detail the distributed mission planning process, dynamic prediction of battle evolution, interoperability, airborne mission planning, mission rehearsal, data filtering/fusion, data protection, communication, testing/validation, artificial intelligence, computer graphics, system architectures, and man/system design. The principle objective was also to assess how these would develop in the future and how such developments would impact upon future mission planning systems. An additional task was to recommend any research and development programs which were identified as being important to future improvements in mission planning systems. Derived from text

N94-11333# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Munich (Germany). Aircraft Div.
IN-FLIGHT AIRCRAFT STRUCTURE HEALTH MONITORING BASED ON SMART STRUCTURES TECHNOLOGY
C. BOLLER and R. DILGER *In* AGARD, Smart Structures for Aircraft and Spacecraft 19 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04
Aircraft are known to be highly complex systems requiring an extensive amount of monitoring because of their safety criticality. To reduce direct operating or life cycle cost a lot of effort was spent on automated monitoring systems. On-board loads monitoring systems for aircraft as well as built in test equipment in avionics systems are already available nowadays. On-board loads monitoring systems however do not monitor damage in-situ and on-board. This still has to be performed on-ground by manual nondestructive testing (NDT) inspection. Smart structures technology is a means which can support development towards automated in-situ monitoring of damage even on-board the aircraft. The paper starts with a brief view on aircraft maintenance cost, describes existing aircraft health and usage monitoring systems as well as NDT procedures, and explains how these procedures could be combined to a smart system using smart materials and structures technology. A strategy is proposed how gradual introduction of smart structures technology into structure health monitoring systems can make this new technology beneficial for aircraft operators in short term. Author (revised)

N94-11334# British Aerospace Aircraft Group, Kingston-upon-Thames (England).
STRUCTURAL HEALTH MONITORING USING EMBEDDED FIBRE OPTIC SENSORS
P. A. TUTTON and F. M. UNDERWOOD *In* AGARD, Smart Structures for Aircraft and Spacecraft 10 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A02/MF A04
Structural health monitoring on military aircraft is currently carried out via strain gauges attached to the surface of the aircraft structure. A parametric system based exclusively on flight parameters is being developed for use on EFA. Both of these systems monitor the airframe fatigue life. With the emergence of Smart Structures technology, a new method of structural health monitoring is feasible that has perceived advantages over the current technology. How fiber optics embedded within a composite laminate can be used to monitor strains within the aircraft structure, and hence its fatigue life is described. Embedded fiber optics can be used to monitor sustained damage - battle or low velocity impact damage, give a full flight history and, with diagnostic capability, unconditioned maintenance would be available. Author (revised)

N94-24091# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AIRCRAFT FLIGHT SAFETY: A BIBLIOGRAPHY [LA SECURITE EN VOL: UNE BIBLIOGRAPHIE]
Dec. 1993 53 p
(AGARD-R-805; ISBN-92-835-0730-4; AD-A274945) Copyright Avail: CASI HC A04/MF A01
A bibliography of publications held by NASA on aspects of aircraft flight safety is provided. The abstracts are listed by the following topics: human errors, injury reduction, engines, structures and materials, aircraft aging, fire, adverse weather, aircraft maintenance, future safety requirements, and miscellaneous items. The bibliography was compiled originally as a contribution to a conference on aircraft flight safety, sponsored jointly by AGARD and the Russian International Integration Association, which was held in Russia in August/September 1993. Author (revised)

N95-14199# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
THE PRINCIPLES OF FLIGHT TEST ASSESSMENT OF FLIGHT-SAFETY-CRITICAL SYSTEMS IN HELICOPTERS [LES PRINCIPES DE L'EVALUATION, DANS LE CADRE DES ESSAIS EN VOL, DES SYSTEMES INDISPENSABLES A LA SECURITE DE VOL DES HELICOPTERES]
J. D. L. GREGORY Aug. 1994 29 p Flight Test Techniques Series
(AGARD-AG-300-VOL-12; ISBN-92-836-1001-6) Copyright Avail: CASI HC A03/MF A01
Modern helicopters usually incorporate many engineering systems (including pilot-aiding systems such as autostabilizers and flight directors) which are essential to the safe and effective use of the helicopter. Where the helicopter can be endangered by failure of a system (or of one of its units), that system is termed flight-safety-critical. In general, the use of those systems should not incur a higher probability of hazard to the helicopter than that considered acceptable from considerations of structural or mechanical failure. In assessing the suitability of a helicopter for its intended mission(s), it has become increasingly important to consider the effects of the various systems provided. In particular, assessments of the implications of systems performance and failures derived from calculation and ground test should be validated by flight tests. This paper seeks to establish the general principles applicable to the testing in flight of any flight-safety-critical system, with emphasis on certification rather than system development. It does not deal with the testing of particular systems, but it is

hoped that readers will find the principles described readily applicable to specific cases. This document has been sponsored by the Flight Mechanics Panel of AGARD. Author (revised)

N95-14893# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Vehicle Integration Panel.
FLIGHT IN AN ADVERSE ENVIRONMENT [LE VOL EN ENVIRONNEMENT HOSTILE]
Nov. 1994 161 p Lecture series held in Brunswick, Germany, 7-8 Nov. 1994, in Lisbon, Portugal, 10-11 Nov. 1994, and in Atlantic City, NJ, 15-16 Nov. 1994
(AGARD-LS-197; ISBN-92-836-1006-7) Copyright Avail: CASI HC A08/MF A02

The environment in which an airplane must operate is a major cause of aircraft accidents. This lecture series focuses on specific aspects of the environment, both natural and man-made, which are the major contributors to these accidents as follows: (1) wake turbulence and the generation of trailing vortex systems; (2) the results of an extensive flight test program concerning winter storms off the east coast of Canada including effect on aircraft operations; (3) electromagnetic effects including electrical discharge properties, in-flight test program, in-flight lightning models and lightning simulation techniques; (4) response of an aircraft to wind shear and methods of detection and quantifying this natural hazard; (5) heavy rain effects on aircraft systems performances in the light of full scale and model tests; (6) measurements of atmospheric turbulence, treatment of aircraft response to random turbulence and discrete gusts. For individual titles, see N95-14894 through N95-14900.

N95-14896# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Dept. of Physics.
ESD AND LIGHTNING INTERACTIONS ON AIRCRAFT
JEAN LOUIS BOULAY *In* AGARD, Flight in an Adverse Environment 19 p (SEE N95-14893 03-03) Nov. 1994
(AGARD-LS-197) Copyright Avail: CASI HC A03/MF A02

Under certain adverse conditions, particularly inside or in the vicinity of clouds, aircraft may be affected by two different electric phenomena: electrostatic discharges and lightning discharges. When electrostatic charges accumulate on an aircraft structure, electric discharges occur. These discharges generate RF interference that severely impairs the operation of onboard radio navigation and communication equipment. Sometimes energetic discharges have direct effects on structural components like radomes, windshields and canopies. Lightning discharges may have a very powerful and dangerous effects on an aircraft in flight. The electromagnetic coupling of any repetitive current pulses through the airframe can upset or deteriorate airborne equipment; and under certain circumstances, lightning flashes may also cause serious direct damage to structural components. Author

N95-14897*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ICING: ACCRETION, DETECTION, PROTECTION
JOHN J. REINMANN *In* AGARD, Flight in an Adverse Environment 27 p (SEE N95-14893 03-03) Nov. 1994
(AGARD-LS-197) Copyright Avail: CASI HC A03/MF A02

The global aircraft industry and its regulatory agencies are currently involved in three major icing efforts: ground icing; advanced technologies for in-flight icing; and tailplane icing. These three major icing topics correspondingly support the three major segments of any aircraft flight profile: takeoff; cruise and hold; and approach and land. This lecture addresses these three topics in the same sequence as they appear in flight, starting with ground deicing, followed by advanced technologies for in-flight ice protection, and ending with tailplane icing. Derived from text

N95-14898# Woodfield (Alan A.), Bedford (England).
WIND SHEAR AND ITS EFFECTS ON AIRCRAFT
ALAN A. WOODFIELD *In* AGARD, Flight in an Adverse Environment 31 p (SEE N95-14893 03-03) Nov. 1994
(AGARD-LS-197) Copyright Avail: CASI HC A03/MF A02

Wind shear has been responsible for several major accidents and many incidents during landing and take off. In aviation terms, wind changes that cause flight path deviations (wind shear) are mainly those occurring over distances between about 150 and 3000m, i.e. approximately 3 to 40 sec. at approach speeds. General characteristics of many forms of wind shear are described together with measured data on the probability of meeting headwind shears of different magnitudes. This is followed by analysis of the basic response of aircraft to both horizontal wind changes and downdrafts, and discussion of aircraft sensitivity to wind shear. Several recorded examples of wind shear in both normal operational and accident scenarios are presented. The relevance of different ways of quantifying wind shear severity is examined, including a calculation of height loss that can be used when a wind shear is fully defined, and the 'F' factor, which is used with reactive wind shear measuring systems. Some insight into the probabilities of false or missed warnings with each system is derived using the measured probability data. A brief outline is given of the relevant characteristics of different wind shear prediction and detection systems. The lecture concludes with a study of the ways in which pilots can be trained and assisted to survive most wind shear encounters and, hopefully, avoid those which could be catastrophic. It is concluded that, given appropriate training and aircraft systems, it is possible to survive encounters with nearly all those wind shears that caused fatal accidents in previous years. New predictive detection systems offer the possibility to warn an aircraft before it attempts to penetrate those extremely rare wind shears that are beyond its performance capability. Author

N95-14899*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HEAVY RAIN EFFECTS
R. EARL DUNHAM, JR. *In* AGARD, Flight in an Adverse Environment 17 p (SEE N95-14893 03-03) Nov. 1994
(AGARD-LS-197) Copyright Avail: CASI HC A03/MF A02

This paper summarizes the current state of knowledge of the effect of heavy rain on airplane performance. Although the effects of heavy rain on airplane systems and engines are generally known, only recently has the potential aerodynamic effect of heavy rain been recognized. In 1977 the United States Federal Aviation Administration (FAA) conducted a study of 25 aircraft accidents and incidents which occurred between 1964 and 1976 in which low-altitude wind shear could have been a contributing factor. Of the 25 cases (23 approach or landing and 2 take-off) in the study, ten cases had occurred in a rain environment, and in five cases these were classified as intense or heavy rain encounters. These results led to the reconsideration of high-intensity, short-duration rainfall as a potential weather-related aircraft safety hazard, particularly in the take-off and/or approach phases of flight. Author

N95-19167# National Research Council of Canada, Ottawa (Ontario). Structures and Materials Lab.
SPECTROGRAM DIAGNOSIS OF AIRCRAFT DISASTERS
F. W. SLINGERLAND *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 6 p (SEE N95-19142 05-71) Sep. 1994 Original contains color illustrations
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

Impulsive forces applied to an aircraft fuselage generate radial vibration waves in the structure analogous to those in a classical thin shell. It has been found that these waves are detected by the cockpit area microphone, and that spectrogram analysis of the microphone recording can provide information on the nature, origin and strength of the source, whether an explosion or a sudden decompression. Author

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

N92-27894*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
STATUS OF AUTOMATIC GUIDANCE SYSTEMS FOR ROTORCRAFT IN LOW ALTITUDE FLIGHT
BANAVAR SRIDHAR, VICTOR H. L. CHENG, and HARRY N. SWENSON *In* AGARD, Air Vehicle Mission Control and Management 12 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

Rotorcraft operating in high-threat environments fly close to the earth's surface to utilize surrounding terrain, vegetation, or man-made objects to minimize the risk of being detected by an enemy. The piloting of the rotorcraft is at best a very demanding task and the pilots need help from on-board automation tools in order to devote more time to mission-related activities. The Automated Nap-of-the-Earth (NOE) Flight Program is a cooperative NASA/Army program aimed at the development of technologies for enhancing piloted low-altitude/NOE flight path management and control through computer and sensor aiding. The long-term objective is to work towards achieving automation for aiding the pilot in NOE flight with a flight demonstration of resulting computer/sensor aiding concepts at an established course. The technology for pilot-centered NOE automation is not currently available. Success in automating NOE functions will depend on major breakthroughs in real-time flight path planning algorithms, effective methods for the pilot to interface to the automatic modes, understanding of visual images, sensor data processing/fusion, and sensor development. Our approach to developing the technologies required to solve this problem consist of the following phases: (1) algorithm development, (2) laboratory evaluation, (3) piloted ground simulation, and (4) evaluation in flight. An overview of the research in this area at NASA Ames Research Center is given. Author

N92-27895# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany). Inst. fuer Systemdynamik und Flugmechanik.
KNOWLEDGE-BASED PLANNING FOR CONTROLLED AIRSPACE FLIGHT OPERATION AS PART OF A COCKPIT ASSISTANT
T. PREVOT (Bundeswehrsanitaetszentrum, Hamburg (Germany, F.R.).), R. ONKEN (Bundeswehrsanitaetszentrum, Hamburg (Germany, F.R.).), and H.-L. DUDEK (Dornier System G.m.b.H., Friedrichshafen, Germany, F.R.) *In* AGARD, Air Vehicle Mission Control and Management 8 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A02/MF A03

A knowledge based computer aid for flight planning tasks as part of a Cockpit Assistant for IFR (Instrument Flight Rules) operation is presented in detail after a brief overview of the modular structure of the Cockpit Assistant has been given. Based upon the requirements of air traffic management, the system is aimed at supporting the pilot in complex planning and decision situations. By assessing the situation, flight goal conflicts are detected and avoided by offering sensible flight plan modifications to the pilot. The main features of the situation assessment and planning module are discussed with regard to knowledge representation and applied solution model. Thus, conflict detection, selection of an alternate destination and rerouting algorithms are described in detail. The present state of implementation, as tested in a flight simulation facility at the University of the German Armed Forces in Munich, is presented as well as some results of the test phase with professional pilots. The possibilities of integrating the system into the avionics of modern aircraft are discussed and an outlook is given of expanding it towards 4-D and RNAV capability and/or optimal 3-D aircraft trajectory planning under constraints from terrain, traffic and weather. Author

N92-27896# Naval Air Development Center, Warminster, PA.
COMPARISON OF THE EVENT-STEP ALGORITHM TO OTHER PATH PLANNING METHODS TO AVOID DYNAMIC 3D OBSTACLES
MARK SILBERT *In* AGARD, Air Vehicle Mission Control and Management 9 p (SEE N92-27887 18-01) Mar. 1992 Revised
(AGARD-CP-504) Copyright Avail: CASI HC A02/MF A03

In a previous paper, the Event-Step Algorithm (ESA) was presented as an efficient path planning algorithm to avoid dynamic obstacles. Dynamic obstacles are defined as obstacles that move and/or distort over time. Here, the focus is more closely on the algorithm; it is compared with other path planning algorithms. Specifically, Grid Search, Voronoi Graph and Visibility Graph methods are considered. It is shown that the ESA offers advantages over these methods and is a generalization and improvement of the Visibility Graph method. A summary of the ESA is presented. Author

N92-27897# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. of Flight Guidance.
ON BOARD PLANNING OF 4D-TRAJECTORIES
V. ADAM and R. KOHRS *In* AGARD, Air Vehicle Mission Control and Management 12 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

The evolution of present day Air Traffic Management (ATM) towards an integrated Air Traffic Management will lead to the introduction of computer based planning systems on the ground side, which communicate with advanced Flight Management Systems onboard the aircraft via automatic data link. An experimental Flight Management System (EFMS) is under development in the frame of the PHARE program for research into future ATM concepts. This EFMS will have the capability to predict a 4-dimensional trajectory according to a set of constraints given by an ATC planning computer on the ground. It will negotiate this trajectory with ATC via data link and will generate appropriate guidance commands for the autopilot/autothrottle system to steer the aircraft along this trajectory. The functionality of the EFMS is described as well as the planning strategy for the generation of a trajectory from the departure to the destination airport which meets the defined constraint attributes. Author

N92-27898# Honeywell, Inc., Minneapolis, MN. Systems and Research Center.
TRAJECTORY OPTIMIZATION FOR HYPERSONIC AIRCRAFT GUIDANCE
R. L. SCHULTZ, M. J. HOFFMAN, A. M. CASE, and S. I. SHEIKH *In* AGARD, Air Vehicle Mission Control and Management 16 p (SEE N92-27887 18-01) Mar. 1992 Sponsored by AFWAL
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

A computationally efficient, real-time trajectory optimization and guidance approach for hypersonic aircraft is described. The optimization approach is based on Euler-Lagrange energy state approximations. A three-dimensional, spherical-earth, aircraft-motion model with constraints on temperature, dynamic pressure, acceleration, and angle of attack is employed. Climb-to-orbit, return-from-orbit, flight-to-designated-landing-site, unpowered-abort, and powered-abort flight conditions are considered. Different performance criterion are used for different problems. Solution methods of varying computational complexity and performance capability are developed. An exact solution to the optimization problem using iteration on adjoint variables is developed. This method is the most exact but is not suitable for on-board processing. However, it serves as the basis of performance comparison for the approximate methods. Approximate solution methods suitable for onboard guidance are developed for the climb-to-orbit problem and the flight-to-a-landing site problem. A computationally efficient method for generating footprints is described. Footprints are used to determine when to start final descent and to identify candidate landing sites under an air-breathing-engine or rocket-engine abort or other emergency conditions. A hypersonic-vehicle guidance, navigation, and control configuration of the complete optimal guidance scheme is described. Sensitivity analysis results are included for climb-to-orbit trajectories. The probability of achieving orbit using the optimal guidance scheme and a stored nominal approach are compared. Author

N92-27900# Mitre Corp., Bedford, MA.
SEARCH ROUTE PLANNING
J. R. VANZANDT *In* AGARD, Air Vehicle Mission Control and Management 14 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

Planning an airborne search for a relocatable target involves minimizing the risk to the crew while maximizing the estimated likelihood of finding targets. When the number of potential sites is small, the problem reduces to finding the best (usually the shortest) route connecting them. The aircraft need not overfly each site, but must only come within sensor range of it. Thus, the search route planning problem can be modeled as a covering salesman problem (CSP) -- a generalization of the traveling salesman problem in which the tour need not visit every city, but every city must be within a certain distance of some city on the tour. The spacefilling curve heuristic for the traveling salesman problem is demonstrated, then a new heuristic for the covering salesman problem is presented and applied to the search route planning problem. When the number of sites is large, the planner must also decide which subset of them can be visited. A genetic algorithm has been developed for selecting both a set of sites to visit and an appropriate routing pattern. The procedure also accounts for the finite turning radius of the aircraft. Author

N92-27901# Electronic System G.m.b.H., Munich (Germany).
AN EFFICIENT METHOD FOR THREE-DIMENSIONAL ROUTE PLANNING WITH DIFFERENT STRATEGIES AND CONSTRAINTS
U. LEUTHAEUSSER and F. RAUPP *In* AGARD, Air Vehicle Mission Control and Management 5 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A01/MF A03

A method for planning paths through a digital map is presented. The task consists of planning 3-dimensional paths for autonomous air vehicles over a terrain represented by a digital map with different strategies and constraints. Possible strategies minimize time, danger, or fuel consumption. Constraints are lateral, and vertical maximum accelerations as well as time and fuel constraints. The path planning problem can be viewed as a shortest path problem (geodesic problem) in a space with a non-Euclidean metric depending on the applied strategy. One has to minimize a cost functional giving rise to the Hamilton-Jacobi equation which is solved by Dynamic Programming techniques. Because of the digitization bias, a second optimization step consisting of direct optimization methods is sometimes necessary. The result is a fast, non-heuristic and flexible technique for strategic route planning. Author

N92-27904# Royal Aircraft Establishment, Farnborough (England). Flight Systems Dept.
PARALLEL KNOWLEDGE BASED SYSTEMS ARCHITECTURES FOR IN-FLIGHT MISSION MANAGEMENT
M. R. BOWYER and S. A. CROSS *In* AGARD, Air Vehicle Mission Control and Management 12 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

The focus here is on the architectural approach, both in hardware and software, taken for the parallel DMuse project, and its applications to in-flight mission management. This includes a description of the Muse Real Time Intelligent Knowledge Based System (IKBS) toolkit as it now stands and the alterations necessary to provide this system on a multi-processor platform to produce the Distributed Muse (DMuse) toolkit. Author

N92-27905# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. of Flight Guidance.
IMPLEMENTATION AND OPERATIONAL EXPERIENCE WITH A NEW ARRIVAL TRAFFIC MANAGEMENT SYSTEM AT THE FRANKFURT ATC-CENTER
M. SCHUBERT and U. VOELCKERS *In* AGARD, Air Vehicle Mission Control and Management 17 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

The DLR-Institute for Flight Guidance had developed a new Arrival Traffic Management System called COMPAS (Computer Oriented Metering Planning Advisory System). The system has been implemented at the Frankfurt Regional Air Traffic Control Center in mid 1989 and is in continuous operation since then. A comprehensive implementation plan was developed in order to guarantee a smooth introduction, in particular with respect to both technical issues and controller acceptance. The experience gained and the lessons learned during the implementation process as well as the operational results are reported. Author

N93-19768# Sextant Avionique, Valence (France).
A VISUAL OF THE HELMET FOR THE PILOTING AND THE DAY/NIGHT NAVIGATION OF THE COMBAT AIRCRAFT: REQUIREMENTS AND TECHNICAL APPROACHES [UN VISUEL DE CASQUE POUR LE PILOTAGE ET LA NAVIGATION JOUR/NUIT DES AERONEFS DE COMBAT: EXIGENCES ET APPROCHE TECHNIQUE]
J. P. CURSOLLE, J. M. KRAUS, and Y. LEFORT *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 9 p (SEE N93-19757 06-54) Oct. 1992 In FRENCH
(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

The requirements of piloting and of day as well as night navigation of a combat aircraft force the man-machine interface into permanent evolution. The last fifteen years brought the spread of 'head high' collimators on combat aircraft. However, in spite of holographic techniques which make it possible to increase the size of the optical field presented, research relating to the improvement of the weapons system has been replaced by the creation of a new interface called 'Helmet Sight' placed in front of the eye of the pilot. This interface enables the pilot to point the sensors of the weapons system in a given direction, and, conversely to show an objective to the navigation and armament system. The size of the optical fields proposed for helmet sights, equivalent to the field of a conventional high head sight, remains insufficient to authorize piloting or navigation in full safety. At most, some parameters can be presented to help the pilot in the realization of his mission. With improving techniques, the existence of this type of interface made it possible to present a more complex image in front of the eyes of the pilot. This is called 'Helmet Sight'. A discussion of the requirements of piloting and navigation in all conditions will highlight the essential criteria taken into account for the design of these new sights. Author

N93-19920# Aerodata Flugmesstechnik G.m.b.H., Brunswick (Germany).
HIGH PRECISION NAVIGATION FOR FLIGHT TESTING (AERONAV)
P. VOERSMANN, M. HAVERLAND, and G. SCHAENZER (Technische Univ., Brunswick, Germany) *In* AGARD, FLight Testing 11 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

The combination of Global Navigation Satellite Systems and inertial sensors can achieve extremely high accuracies in position, speed, turn rate, attitude, and acceleration of a flight vehicle. This paper presents the application of AeroNav to flight testing. AeroNav is an Integrated Navigation system, which has been co-developed between Aerodata and the Institute of Flight Guidance of the Technische Universitat Braunschweig. Due to its tight coupling between satellite and inertial sensors it can be used as the basic system for flight performance measurements and handling quality testing. Furthermore it has the potential to meet the accuracy requirements as position reference for autoland certification and ILS/MLS flight calibration. Flight and ground test results are shown, which use an independent position reference for accuracy validation. Author

N93-19924# Test Wing (6510th), Edwards AFB, CA.
TESTING OF AN AUTOMATIC, LOW ALTITUDE, ALL TERRAIN GROUND COLLISION AVOIDANCE SYSTEM
M. A. SKOOG and T. H. ASCOUGH *In* AGARD, Flight Testing 20 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

Flight test results and analysis techniques are presented for an automatic All Terrain Ground Collision Avoidance System (AT GCAS). The AT GCAS was flight demonstrated on the Advanced Fighter Technology Integration (AFTI)/F-16 and hosted on a production digital F-16 flight control system. Over 200 automatic recoveries were initiated at dive angles up to 50 degrees, all bank angles, and airspeeds ranging from 270 to 570 knots. New methods were developed to analyze data, allowing identification

of subsystem error contributions. The resulting system performance is presented with conclusions. Author

N93-22780# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
INTEGRATED AND MULTI-FUNCTION NAVIGATION [LES SYSTEMES DE NAVIGATION INTEGRES MULTIFUNCTIONS]
Nov. 1992 169 p Meeting held in Ottawa, Ontario, 14-15 May 1992
(AGARD-CP-525; ISBN-92-835-0693-6; AD-A263504) Copyright Avail: CASI HC A08/MF A02

This volume contains the 14 unclassified papers, presented at the Guidance and Control Panel Specialists' Meeting held in Ottawa, Canada from 14th-15th May 1992. The papers were presented covering the following headings: (1) mission applications; (2) sensors for integrated navigation and multi-function reference systems; and (3) design of integrated and multifunctional navigation systems. For individual titles, see N93-22781 through N93-22794.

N93-22781# National Defence Headquarters, Ottawa (Ontario). Directorate Research and Development Communications and Space.
MISSION REQUIREMENTS AND APPLICATIONS OF INTEGRATED AND MULTI-FUNCTION NAVIGATION SYSTEMS
DAVID FESENG LIANG *In* AGARD, Integrated and Multi-Function Navigation 20 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A03/MF A02

Advanced guidance, control and navigation systems are becoming more functional and integrated. This paper describes Canadian experience in the development and applications of Integrated and Multi-function Navigation Systems. The emphasis is on the development of two distinct mission-specific inertially based integrated navigation systems. In particular, in a high risk development project such as the Synthetic Aperture Radar Motion Compensation System, the special attention given to the detailed assessment of key error sources and a well-planned sequence of simulation, development and flight test evaluation are essential to the success of the project. For Multifunctional inertially-based systems, the hardware design emphasis should be on IMU architectures that minimize both the acquisition and life-cycle cost, while the software design emphasis should be on practical and efficient FDIR schemes. Some comments were also offered on the trends of GPS related future applications. Author

N93-22782# Wright Lab., Wright-Patterson AFB, OH. Avionics Directorate.
OPPORTUNITIES AND CHALLENGES IN AVIONICS INTEGRATION, INS/GPS: A CASE STUDY
ZDZISLAW H. LEWANTOWICZ (Air Force Inst. of Tech., Wright-Patterson AFB, OH.) and DANNY W. KEEN (Aeronautical Systems Div., Wright-Patterson AFB, OH.) *In* AGARD, Integrated and Multi-Function Navigation 8 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A02/MF A02

Several recent technological developments (including the advent of GPS and the virtual explosion of computational capability) offer unprecedented opportunities for radically different approaches to providing weapon system capabilities. In the past high-rate raw sensor data would have to be sampled, or significantly pre-processed in a separate (dedicated) computer, before such data could be used within the constraints of a real time weapon system application. During such sampling/pre-processing much of the information content could be lost. The current computational capability explosion now permits highly complex algorithmic solutions to be executed within real time. Such computational capabilities within an integrated avionics architecture offer opportunities for maximum rate fusion of all raw signals directly from the sensors, where they are generated, with little or no information loss. As an example, when unfiltered GPS information is directly/optimally combined at maximum rate with inertial data, not only is the navigation accuracy increased, but effective susceptibility to GPS signal dropout/jamming is significantly reduced. Additionally, the resultant highly precise GPS/INS position, velocity, attitude, and time information can serve as a common integrating agent for combining the information from a variety of other mission sensors and communication devices. A system engineering process is required to systematically explore and exploit the yet untapped opportunities presented by these technological advancements. The essential ingredients of this process are a system level perspective, sound modeling and simulation, and the application of analytic tools. Author

N93-22787# Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France).
OPTIMIZATION OF THE INTEGRATION OF INERTIA AND GPS [INTEGRATION OPTIMISEE DE L'INERTIE ET DU GPS]
M. LOIEC CAMBERLEIN, BERNADETTE CAPIT, and M. PASCAL DEBANNE *In* AGARD, Integrated and Multi-Function Navigation 9 p (SEE N93-22780 08-04) Nov. 1992 In FRENCH
(AGARD-CP-525) Copyright Avail: CASI HC A02/MF A02

ULISS NG is an Inertia-GPS unit and an interesting example of INS/GPS synergy and performance/cost trade-off. It belongs to the ULISS family of INS already fitted to a number of different aircraft. Its miniaturized code twelve channel embedded receiver, with its RF and digital modules, totals 0.7, 1, 7 kg and 12 W. Its parallel tracking maximizes navigation continuity, smoothness, accuracy and minimizes reaction time and oscillator size. The tight Inertia-GPS coupling, i.e., tight inertial aiding and tight hybrid navigation Kalman filter, has been designed to favor operational capabilities, performance and solution stability. Four versions of the SAGEM embedded GPS receiver have been developed C/A-SPS, C/A-SA-PPS and P(Y)L1 and P(Y)L1/L2. The P code version is presented in the paper. Flight tests are being conducted in a Mirage 3 at the French Official Flight Test Center of Bretigny starting in May. Author

N93-22788# GEC Ferranti, Edinburgh (Scotland). Navigation Systems Div.
RETROFITTING OF GPS INTO EXISTING NAVIGATION SUITES
D. I. CALLENDER and N. F. WATSON *In* AGARD, Integrated and Multi-Function Navigation 18 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A03/MF A02

As GPS signal availability reaches operationally useful levels, and in particular following experience of its usefulness in the Gulf operations, widespread requirements are beginning to arise for the incorporation of GPS into existing combat aircraft. A considerable amount of study and development work has been carried out by GEC Ferranti to investigate different approaches to integrating GPS into existing navigation systems with the minimum impact on installation, interfacing and operating procedures. This paper describes some different approaches to integrating GPS together with their relative merits and deficiencies. Two practical systems are described in detail and some simulation and trials results are presented together with some aspects of the GPS integration which will form the basis of future development work. Author

N93-22789# Technische Univ., Brunswick (Germany). Inst. of Flight Guidance and Control.
INTEGRATED PRECISION NAVIGATION SYSTEM
G. SCHAENZER and B. TIEMEYER *In* AGARD, Integrated and Multi-Function Navigation 10 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A02/MF A02

Combined Satellite and Inertial Navigation Systems can achieve extremely high positioning accuracies in the sub meter range even in the dynamic environment of aircraft. This paper presents the concept of the 'Integrated Navigation System' developed at the Institute of Flight Guidance using coupled satellite and inertial sensors. Flight test results are shown, which demonstrate that this system has the potential to achieve the accuracy requirements according to ICAO CAT 3 for high precision approaches even under bad weather conditions. Author

N93-22790*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FLIGHT EVALUATION OF DIFFERENTIAL GPS AIDED INERTIAL NAVIGATION SYSTEMS
B. DAVID MCNALLY, RUSSELL A. PAIELLI, RALPH E. BACH, JR., and DAVID N. WARNER, JR. *In* AGARD, Integrated and Multi-Function Navigation 17 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A03/MF A02

Algorithms are described for integration of Differential Global Positioning System (DGPS) data with Inertial Navigation System (INS) data to provide an integrated DGPS/INS navigation system. The objective is to establish the benefits that can be achieved through various levels of integration of DGPS with INS for precision navigation. An eight state Kalman filter integration was implemented in real-time on a twin turbo-prop transport aircraft to evaluate system performance during terminal approach and landing operations. A fully integrated DGPS/INS system is also presented which models accelerometer and rate-gyro measurement errors plus position, velocity, and attitude errors. The fully integrated system was implemented off-line using range-domain (seventeen-state) and position domain (fifteen-state) Kalman filters. Both filter integration approaches were evaluated using data collected during the flight test. Flight-test data consisted of measurements from a 5 channel Precision Code GPS receiver, a strap-down Inertial Navigation Unit (INU), and GPS satellite differential range corrections from a ground reference station. The aircraft was laser tracked to determine its true position. Results indicate that there is no significant improvement in positioning accuracy with the higher levels of DGPS/INS integration. All three systems provided high-frequency (e.g., 20 Hz) estimates of position and velocity. The fully integrated system provided estimates of inertial sensor errors which may be used to improve INS navigation accuracy should GPS become unavailable, and improved estimates of acceleration, attitude, and body rates which can be used for guidance and control. Precision Code DGPS/INS positioning accuracy (root-mean-square) was 1.0 m cross-track and 3.0 m vertical. (This AGARDograph was sponsored by the Guidance and Control Panel.) Author

N93-22791# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany). Dept. of Aerospace Technology.
VISUAL AUTONOMOUS AUTOMATIC LANDING OF AIRPLANES
E. D. DICKMANNS and F.-R. SCHELL *In* AGARD, Integrated and Multi-Function Navigation 9 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A02/MF A02

A visual sensor data processing method has been developed and validated which allows to achieve on board autonomous landing approaches in the visual flight regime with computing technology available today; sensors are a video-camera, inertial gyros and an air velocity meter. The key feature of the method is the reconstruction and servo-maintained adjustment by prediction error feedback of an internal spatio-temporal model about the process to be controlled (4D approach). This encompasses both the ego motion state of the aircraft carrying the sensors and the relevant geometric properties of the runway and its spatial environment. The efficiency of the approach is proved both in a hardware-in-the-loop simulation and in real test-flights with a twinturbo-prop aircraft Do 128 of Dornier. For accuracy evaluation of the data gathered, the results of differential GPS and radio metric altitude measurements have been recorded simultaneously. Author

N93-22792# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. of Flight Guidance.
SCENE CORRELATION FOR INS AIDING IN FLIGHT-TEST SYSTEMS: RUNWAY-REFERENCED FLIGHT-TESTS WITH ON-BOARD SENSORS ONLY
B. STIELER and H.-U. DOEHLER *In* AGARD, Integrated and Multi-Function Navigation 15 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A03/MF A02

Inertial and image-derived measurements for runway referenced flight path computations are investigated. They open the way for flight-tests without ground-based sensors and with a minimum of a priori knowledge or none at all about the runway position and direction in absolute coordinates. They are ideally suited for inspecting landing aids at congested civil airports, for instance. The investigations concentrate on the problems of the baroinertial and inertial altitude measurements, on the achievable accuracies of image-derived measurements and their integration with inertial measurements. It is shown that glide path and flight track accuracies in the order of 0.01 deg (1 sigma) should be achievable. Author

N93-22793# Defence Research Establishment Ottawa, Ottawa (Ontario). Communication and Navigation Section.
AN HIERARCHIC ALLIANCE OF FILTERS FOR FAULT TOLERANT NAVIGATION USING TWO INERTIAL SYSTEMS WITH AIDING SENSORS
J. CHRIS MCMILLAN, JEFF S. BIRD, and DALE A. G. ARDEN (Computers and Concepts Associates, Ontario.) *In* AGARD, Integrated and Multi-Function Navigation 11 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A03/MF A02

A Dual Inertial Integrated Navigation System (DIINS) is being developed for the Canadian Navy to improve the navigational accuracy and reliability on ships which have two inertial navigators plus other aiding navigation systems and sensors such as GPS, Loran-C, Omega, Doppler Speed Log(s) and so on. The sensor integration architecture being proposed to optimally combine all navigation sensors on such a vessel is an 'hierarchic alliance' of Kalman filters, which is designed to allow sensitive error compensation as well as complete fault detection isolation and reconfiguration (FDIR). This architecture is ideally suited to central processing, can take advantage of parallel processing, and provides significant advantages over both the conventional unifilter approach and the 'federated' (or cascaded) filter approach. This hierarchic alliance consists of a specific set of optimal filters running in parallel, with each filter processing measurements from a different subset of the navigation sensors. These filters can be partially ordered so that primary and secondary filters can be defined. The primary filter(s) provide the optimal navigation solution, while the secondary filters provide uncorrupted backup in the event of a sensor fault. The primary motivating factor for this architecture is to provide optimal integration under all conditions, and in particular after the occurrence of subtle sensor faults which could not be immediately detected and which could therefore corrupt the primary filter(s). This alliance of filters can provide an uncorrupted optimal solution, since it can be configured so that there will always be a secondary filter which, at the time of failure, was running independently of the faulty sensor. This removes the usual need to 'back out' of a failure which was not immediately detected and thus substantially simplifies reconfiguration in response to such a failure. Another motivating factor for this architecture is that the partial independence of the parallel filters also facilitates the detection and isolation of sensor faults. This can be accomplished by multiple levels of statistical hypothesis testing on a set of parallel Kalman filters. Fault detection techniques used include the usual sensor data reasonableness and filter residual tests as well as a chi-square hypothesis testing technique applied to the state vectors, and inter-filter voting applied to the residuals test results. While this approach is computationally intensive, modern software techniques, and soon to be available processing power, are expected to make the real time implementation of this hierarchic alliance of filters quite practical. The system envisioned in this paper is being designed and built at the Defence Research Establishment Ottawa for the Canadian Navy and is expected to see initial real-time sea trials in 1993. Author

N93-22794*# Ohio Univ., Athens, OH. Avionics Engineering Center.
TOWARD ACHIEVING GLOBAL SOLE MEANS RADIONAVIGATION SYSTEMS
F. VANGRAAS *In* AGARD, Integrated and Multi-Function Navigation 10 p (SEE N93-22780 08-04) Nov. 1992
(Contract(s)/Grant(s): NGR-009-017; DTRS-57-87-C-00006)
(AGARD-CP-525) Copyright Avail: CASI HC A02/MF A02

This paper briefly reviews tentative requirements for global, earth-referenced sole means of navigation systems with emphasis on integrity and availability. These requirements can be allocated to integrated navigation system architectures based on for instance GPS, GLONASS, VOR/DME, TACAN, Omega, Chayka, and

Loran-C. Fault detection and isolation techniques (FDI) for integrated radio navigation systems are presented. The FDI algorithm provides a protection radius with a specified confidence level as a function of measurement geometry and algorithm requirements. This is followed by a case study of integrated GPS/Loran-C. Author

N94-29323# Wright Lab., Wright-Patterson AFB, OH.
OBJECT ORIENTED DESIGN OF THE AUTONOMOUS FIXTAKING MANAGEMENT SYSTEM
JOSEPH DIEMUNSCH and JOHN HANCOCK *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 14 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

The Air Force Avionics Laboratory has sponsored several efforts to increase the accuracy of aircraft navigation functions while decreasing crew workload through the application of intelligent systems. Two such efforts were the Adaptive Tactical Navigation (ATN) System and the Autonomous Fixtaking Management (AFM) system, which were both awarded to The Analytic Sciences Corporation (TASC). An intelligent system to aid the pilot with navigation functions was developed under the ATN program. This system incorporated real-time knowledge base software to manage the tactical navigation moding, fault tolerance, and pilot aiding to provide a robust navigation prototype for the next generation fighter aircraft. The ATN program highlighted the aircraft weapons officer's heavy workload associated with the location and identification of fixpoints to update and verify the accuracy of the navigation system. With this problem in mind, it was determined that an intelligent system was needed to automatically locate, image, and identify fixpoints and update the navigation solution. The AFM System was developed to prove the feasibility of automated navigation updates using tactical sensors and existing mission data processing systems. Several technologies developed under ATN were incorporated into the AFM system including a proven simulation of the navigation sensors, controllers, and mission planning and management software. Automation of human fix taking activity required integration of several emerging technologies including a real-time data fusion architecture, neural network and heuristic automatic recognition algorithms, and associative memories to retrieve fix points from on-board databases. Integration of these diverse technologies was simplified by the employment of an object-oriented software development approach and real-time control system. Derived from text

N94-29558# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
MACHINE INTELLIGENCE IN AIR TRAFFIC MANAGEMENT [L'INTELLIGENCE ARTIFICIELLE DANS LA GESTION DU TRAFIC AERIEN]
ANDRE BENOIT, ed. (European Organization for the Safety of Air Navigation, Brussels, Belgium.) Oct. 1993 400 p In ENGLISH and FRENCH The 56th Symposium was held in Berlin, Germany, 11-14 May 1993
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This volume contains the Technical Evaluation Report and the 30 papers, presented at the Guidance and Control Panel Symposium held in Berlin, Germany from 11th to 14th May 1993. The papers were presented covering the following headings: Air Traffic Processes; Novel Approaches; Transition to Operation; Human/Machine Relationship; Air/Ground Integration; PHARE; and Ground Movements Control. For individual titles, see N94-29559 through N94-29587.

N94-29559# Mitre Corp., McLean, VA. Center for Advanced Aviation Systems Development.
ADVANCES IN DEVELOPMENT CAPABILITIES FOR INTELLIGENT AIR TRAFFIC MANAGEMENT SYSTEMS
KERRY M. LEVIN and JOHN J. FEARNSIDES *In* AGARD, Machine Intelligence in Air Traffic Management 18 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

Visual presentation is a major source of information for air traffic control. Significant advances in computers, display technology, and the tools used by developers of intelligent air traffic management (ATM) systems pose challenges for the development of computer-human interfaces (CHI's) associated with the new automation. The CHI must be designed to be both usable and suitable. This paper reviews three capabilities available to developers of intelligent ATM systems: case-based reasoning system design, rule-based system design, and individually tailored CHI. It recommends that any intelligent ATM system be examined early in its development cycle in a laboratory environment, where it can be tested in concert with other elements of the ATM system. Author

N94-29560# CompEngServ Ltd., Ottawa (Ontario).
INTELLIGENT SYSTEMS FOR AIR SPACE CONTROL AND MANAGEMENT
DAVID BOWEN and ANDRZEJ HLIBOWICKI *In* AGARD, Machine Intelligence in Air Traffic Management 11 p (SEE N94-29558 08-04) Oct. 1993 Sponsored by Transportation Development Centre
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

Complete automation of an air traffic control system requires the identification of functions and their allocation to a distributed system, part of which is on the ground and part of which flies. The evolution of current systems appears to be taking place with ill-defined visions of what the final system will or should look like. In some cases this fuzzy view of the future is purposely carried because of the implications of proposing a view which antagonizes various groups or associations representing those already engaged in the process. Yet, each step along the way implies explicitly or implicitly some final target system. As each year goes by, we move toward a system which may be a long way from what is really desirable in the next century. It seems reasonable that some versions of the ideal future system should be understood within the community. At least one of these options should be what is technically feasible. From this, an acceptable system can be negotiated. The first step in this process is to determine the desired functionality without regard to any other factors. From this, technical feasibility can be determined and/or predicted; and finally, the allocation of the functions to humans or machines can be debated. The management of a dense cluttered air space requires a set of skills and capabilities on the part of an air traffic control team which, in some of their functions, cannot be represented algorithmically. Successful automated air traffic management systems will necessarily emulate the intuitive portions of the human management capability using various technologies drawn from the broad field of artificial intelligence. Indeed portions of the overall management system have been the subject of research and development efforts in many laboratories around the world. The integration of these fragments into an overall scheme is often left as an implicitly understood architecture. This paper begins by presenting CompEngServ (CES) Ltd.'s view of an automated airspace management system. The paper then presents an overview of the prototype of an advanced controller workstation developed by CES (under contract to Transport Canada) which prototypes various portions of this architecture for Airspace Management. This system represents the state of the art in Air Traffic Control (ATC) research. This prototype is also an example of multiple hardware and software technologies being harnessed to develop a solution to a problem initially thought to be too complex for automation. The paper then presents the future direction of research at CES and then closes with the issues which have been raised by our work that need addressing before an automated system will be practical. Author

N94-29561# Centre d'Etudes de la Navigation Aerienne, Toulouse (France).
USE OF ADVANCED TECHNOLOGIES IN ATM (AIR TRAFFIC MANAGEMENT) DOMAIN
P. PLANCHON and M. BONNARD *In* AGARD, Machine Intelligence in Air Traffic Management 11 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

The CENA is in charge of studies related to Air Traffic Management and therefore to some of the communication, navigation, and surveillance means. The work is carried out to support French and European ATC (air traffic control) in an international cooperation. It encompasses studies and experimental development aiming at operational implementation within the CAUTRA 5 program. The different CENA projects are integrated in an experimental simulator frame named ADER. This test-bed

will support one of the demonstrations within PHARE, a joint European experimental program. The CENA organization is based upon a technical directorate in charge of the horizontal projects as previously described and 10 divisions located either at Athis-Mons (near Paris) or in Toulouse. One of these divisions, called COA (Control Organization and Automation), deals mainly with studies aiming at providing ATM (air traffic management) operators with helpful decision tools, using advanced methods and technologies. In this paper, it can be found a short description of COA division activities and a more precise analysis of one of the projects, called GOETHE, aiming to provide ATFM (Air Traffic Flow Management) regulators with a more user-friendly tool.
Derived from text

N94-29562# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
AIR TRAFFIC MANAGEMENT AS PRINCIPLED NEGOTIATION BETWEEN INTELLIGENT AGENTS
ROBERT STENGEL and JOHN WANGERMANN *In* AGARD, Machine Intelligence in Air Traffic Management 10 p (SEE N94-29558 08-04) Oct. 1993
(Contract(s)/Grant(s): DT-FA01-92-G-0011)
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The major challenge facing the world's aircraft/airspace system (AAS) today is the need to provide increased capacity, whilst reducing delays, increasing the efficiency of flight operations, and improving safety. Technologies are emerging that should improve the performance of the system, but which could also introduce uncertainty, disputes, and inefficiency if not properly implemented. The aim of our research is to apply techniques from intelligent control theory and decision-making theory to define an Intelligent Aircraft/Airspace System (IAAS) for the year 2025. The IAAS would make effective use of the technical capabilities of all parts of the system to meet the demand for increased capacity with improved performance. Author

N94-29563# Shape Technical Center, The Hague (Netherlands).
USE OF GPS IN AUTOMATED AIR TRAFFIC CONTROL
HERMANN F. HEGELS and WILLEM E. HOEKSTRA *In* AGARD, Machine Intelligence in Air Traffic Management 26 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

The Global Positioning System NAVSTAR is rapidly becoming the world standard for navigation and timing. Although primarily designed to be a military system, the civil user community is expanding at a breathtaking pace. After an introduction to the general GPS policies and the technical fundamentals this paper presents an idea on how to use GPS NAVSTAR to improve Air Traffic Control. Existing selective identification features will form the key to a GPS-based position, velocity, and acceleration message. Higher update rates and the vastly improved information on each aircraft will provide the input for a flight plan correlation function enabling an automatic air traffic monitoring and control far beyond current standards. Author

N94-29564# Raumfahrt Systemtechnik G.m.b.H., Salem (Germany).
GROUND INDEPENDENT LANDING SYSTEM
HANS MARTIN BRAUN and PHILIPP HARTL *In* AGARD, Machine Intelligence in Air Traffic Management 6 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A02/MF A04

Air traffic in Central Europe is dramatically increasing today. There are some indications that present upgrades of the air traffic control system might not be efficient and that planned upgrades will not be realized in time due to budgetary restrictions. One key element in air traffic control is a precise navigation of the aircraft during landing, the most critical part of the flight. It is presently performed by use of the instrument landing system ILS and in some areas already by the microwave landing system MLS. The latter provides a very high navigation performance and allows a high landing sequence under all weather conditions. However, it requires extensive ground equipment at the airports and hence, only a few airports in Central Europe are equipped with it today. This paper presents the results of a study on a new microwave landing system with a spaceborne radar transmitter and airborne radar receivers. Based on this bistatic radar system, navigation in landing phase could also be performed independently from weather conditions. However, it does not require any active equipment at the landing site. Even taxi way guidance could be performed with this system. It is called 'Ground Independent Landing System' (GILS). Author

N94-29565# Deutsche Aerospace A.G., Ulm (Germany).
GPS/GNSS FOR ATM
THOMAS JACOB, JOCHEN MEYER-HILBERG, GERHARD BANTLE, WINIFRED ROESCH, HEINZ-GEORG WIPPICH, and HORST SCHMIDT *In* AGARD, Machine Intelligence in Air Traffic Management 10 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A02/MF A04

The actual implemented Air Traffic Control (ATC) systems have radar coverage gaps on the Northern Atlantic and Trans-Siberian Routes as well as in the Pacific area. This situation results in insufficient air traffic surveillance information in the corresponding control sectors and larger separation between aircraft on these routes to ensure safe operation. Unfortunately, this procedure reduces the capacity and limits air traffic flow. These problems can be overcome by the worldwide use of the high accurate position data from Global Navigation Satellite Systems (GNSS) such as the U.S. Global Positioning System (GPS) and the Russian Global Navigation System (GLONASS) aboard the aircraft as proposed by the ICAO-FANS plan. In combination with the Automatic Dependent Surveillance (ADS) function as specified by ARINC 745, the onboard computed position and flight path data is transmitted to the Aeronautical Telecommunication Network (ATN) for further use by ATM and ATC. Based on these principles, Deutsche Aerospace AG, Airborne Systems Division has developed a demonstrator. This system integrates the precise (Differential) GNSS information with the data from an Inertial Measurement Unit (e.g. AHRS) aboard the demonstrator aircraft to fulfill the accuracy and consistency/integrity requirements during all phases of flight. This system integration has been done to ensure integrity of GNSS position information during satellite outages or satellite masking, e.g. during turns. For demonstrating ADS-functionality, the onboard computed position and flight path velocity is transmitted in combination with flight management information to the ground system using a data link. In addition to this en-route ADS function with medium accuracy requirements, a high accuracy mode using Differential GNSS data for conflict detection calculations between low separated aircraft has been implemented. The conflict detection and alert functions are based on a special designed Expert System capable of real time operation. A taxi monitoring function can also be performed by the system. All system functions have been tested and demonstrated during flight trials using a VHF data link for communication. Results of these flight tests will be presented. Author (revised)

N94-29567# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. of Flight Guidance.
CONTRIBUTIONS OF DLR TO AIR TRAFFIC CAPACITY ENHANCEMENT WITHIN A TERMINAL AREA
U. VOELCKERS, U. BROKOF, D. DIPPE, and M. SCHUBERT *In* AGARD, Machine Intelligence in Air Traffic Management 11 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

Enhancement of air traffic capacity within the TMA cannot be achieved easily. Single solutions and improvements of technical equipment, procedures and standards, with automation support for human operators in isolated areas, e.g. for the management of the airport, airspace and Air Traffic Control very often will only yield marginal capacity increases. Whether it is: new concrete (runways, taxiways, aprons), reduced separation minima, or advanced ATM functions, all these measures will only result in significant capacity increases, if they are designed, developed and implemented in a comprehensive, combined effort, making use of set of complementary measures and functions in a well structured, optimized architecture and implementation strategy. This comprehensive approach is especially true for high density TMA's/airports, operating close to capacity limits, where any capacity enhancement measure will directly affect and/or require capacity related issues in other areas. Based upon the specific needs of the Frankfurt airport and TMA, DLR is working on a variety of tools and functions, which--combined and implemented in a well designed strategy plan--can yield significant capacity increases without the construction of new runways. Three candidate

systems--under development or even already in operation--which mutually depend on and complement one another will be presented as examples of an even larger capacity enhancement plan for the TMA. Derived from text

N94-29568*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DESIGN OF CENTER-TRACON AUTOMATION SYSTEM
HEINZ ERZBERGER, THOMAS J. DAVIS, and STEVEN GREEN *In* AGARD, Machine Intelligence in Air Traffic Management 12 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

A system for the automated management and control of terminal area traffic, referred to as the Center-TRACON Automation System (CTAS), is being developed at NASA Ames Research Center. In a cooperative program, NASA and FAA have efforts underway to install and evaluate the system at the Denver area and Dallas/Ft. Worth area air traffic control facilities. This paper will review CTAS architecture, and automation functions as well as the integration of CTAS into the existing operational system. CTAS consists of three types of integrated tools that provide computer-generated advisories for both en-route and terminal area controllers to guide them in managing and controlling arrival traffic efficiently. One tool, the Traffic Management Advisor (TMA), generates runway assignments, landing sequences and landing times for all arriving aircraft, including those originating from nearby feeder airports. TMA also assists in runway configuration control and flow management. Another tool, the Descent Advisor (DA), generates clearances for the en-route controllers handling arrival flows to metering gates. The DA's clearances ensure fuel-efficient and conflict free descents to the metering gates at specified crossing times. In the terminal area, the Final Approach Spacing Tool (FAST) provides heading and speed advisories that help controllers produce an accurately spaced flow of aircraft on the final approach course. Data bases consisting of several hundred aircraft performance models, airline preferred operational procedures, and a three dimensional wind model support the operation of CTAS. The first component of CTAS, the Traffic Management Advisor, is being evaluated at the Denver TRACON and the Denver Air Route Traffic Control Center. The second component, the Final Approach Spacing Tool, will be evaluated in several stages at the Dallas/Fort Worth Airport beginning in October 1993. An initial stage of the Descent Advisor tool is being prepared for testing at the Denver Center in late 1994. Operational evaluations of all three integrated CTAS tools are expected to begin at the two field sites in 1995. Derived from text

N94-29569# National Aerospace Lab., Amsterdam (Netherlands).
SIMULATION OF FULLY AUTOMATED AIR TRAFFIC CONTROL CONCEPTS
WIM DENBRAVEN and HANS VANDENBOS *In* AGARD, Machine Intelligence in Air Traffic Management 16 p (SEE N94-29558 08-04) Oct. 1993 Sponsored by Schiphol Airport Authorities
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

In order to be able to investigate various aspects of the complex Air Traffic Control (ATC) system of the future, a real-time ATC simulation facility has been constructed at NLR. The ATC automation environment of this simulator is provided by CTAS, the Center/TRACON Automation System, developed by the NASA Ames Research Center. For the simulation of air traffic, radar observations, and data link, the NLR ATC Research Simulator (NARSIM) is used. The facility can be used at various levels of automation, ranging from conventional, 'manual' ATC to fully automatic control. For the latter, CTAS has been extended with various decision and control algorithms, dealing with tasks normally executed by the air traffic controller. In a set of real-time simulation experiments different concepts of fully automated ATC are investigated, characterized by various combinations of control functions and different levels of air-ground interaction. Furthermore, the effect of different levels of aircraft navigation performance is studied. The traffic samples are based on single-runway IFR operations for Schiphol Airport, with the traffic mix and distribution based on predictions for the year 2000. The Dutch airspace is simulated with one overall area control sector, controlling traffic from all directions to the three arrival gates, and one Schiphol approach sector, merging the aircraft from these gates into a properly spaced sequence on final approach. For the analysis of the simulations, methods are under development to present overall ATC system performance in terms of safety, flight efficiency, capacity, and control performance. The results of the simulations are used to determine critical areas in ATC system automation, as well as potential benefits thereof. They can also contribute to an optimal distribution of tasks between man and machine in the ATC system of the future. Author (revised)

N94-29570# European Organization for the Safety of Air Navigation, Brussels (Belgium).
DECISION MAKING AIDS (DMA) IN ON-LINE ATC SYSTEMS
ANDRE BENOIT, JEAN-MARC POMERET, and SIP SWIERSTRA *In* AGARD, Machine Intelligence in Air Traffic Management 11 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

This paper covers the potential of Decision Making Aids to be implemented before the year 2000 and, within the time frame considered, covers all of the aspects of automated assistance, based on flight path prediction and monitoring, which help air traffic controllers to establish and assess the predicted traffic situation more efficiently. Problem detection, problem minimization, and 'best next clearance' advisories will permit the reduction of the controller's mental workload without decreasing the level of safety or the controller's situational awareness. Author (revised)

N94-29571# Centre d'Etudes de la Navigation Aerienne, Toulouse (France).
COGNITIVE APPROACH TO SPECIFICATIONS ON AIR TRAFFIC CONTROLLERS' DECISION ASSISTANCE SYSTEMS [UNE APPROCHE COGNITIVE POUR LA SPECIFICATION D'AIDES A LA DECISION POUR LES CONTROLEURS AERIENS]
MARCEL LEROUX *In* AGARD, Machine Intelligence in Air Traffic Management 10 p (SEE N94-29558 08-04) Oct. 1993 In FRENCH
(AGARD-CP-538) Copyright Avail: CASI HC A02/MF A04

The central problem of this investigation is the creation of an Air Traffic Control System (ATC) involving both man and machine. The present document reports on two examples which typify the man-machine relationships in systems which are partly automated. In one case, the part played by the machine is detrimental to man's involvement; in the other case, man and machine work together for better results. The manner in which this second approach was used during the development of the CENA's ERATO project is described. Transl. by FLS

N94-29572# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. for Flight Guidance.
CONSIDERATIONS ON GRAPHICAL USER INTERFACES FOR INTELLIGENT ATM SUPPORT SYSTEMS
R. BEYER *In* AGARD, Machine Intelligence in Air Traffic Management 13 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

Considerations on the design of graphical user interfaces (GUI's) for air traffic controllers are presented in the context of a European Air Traffic Management System (EATMS). The fundamental issues discussed include the following: air traffic controller tasks; human information processing and mental models; and automation strategies with respect to the GUI design. The more specific issues of GUI design which are also discussed include the following: GUI programming environments and standards; development tools; design principles and human factors/human engineering standards; and usability testing. Conclusions are drawn regarding the current background of GUI design with respect to an EATMS and necessary future developments. Author (revised)

N94-29573# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. for Flight Guidance.
INTERACTIVE ANALYSIS AND PLANNING TOOLS FOR AIR TRAFFIC AND AIRSPACE MANAGEMENT
S. E. MAHLICH *In* AGARD, Machine Intelligence in Air Traffic Management 13 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

Since 1989, the Institute for Flight Guidance of the German Aerospace Research Establishment (DLR) has been developing prototypes of interactive tools in close cooperation with the German Air Navigation Services (DFS) in order to achieve gradual improvements in the efficiency and productivity of the air traffic

control system. The paper briefly describes the potential of a selection of analysis and planning tools that have been developed in this framework. After an introduction into the 'planning world' of tactical and strategical air traffic planning, the objectives and potentials of four tools will be demonstrated as applied to real traffic scenarios and actual problems of the current ATM system.
Author (revised)

N94-29574# Alcatel ISR, Evry (France).
DAISY: A DECISION AID FOR AN AIR SITUATION INTERPRETATION SYSTEM
N. BICHAT, R. ALLOUCHE, and A. BORIES *In* AGARD, Machine Intelligence in Air Traffic Management 8 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A02/MF A04
Due to increases in air traffic volume and the evolution of operational missions, Alcatel ISR has been awarded a contract to analyze the requirements of military air traffic controllers, especially in the area of the air situation interpretation and the implementation of a mock-up. DAISY is aimed at providing controllers with a decision aid for an air situation interpretation system. In this context, interpretation stands for all the rules and combined information which give an operational meaning to the air situation. Abnormal situations are highlighted, a diagnosis is given, and a proposal is made for decision. After a requirements analysis is conducted, both by experts and controllers during six months, a twelve-month technical feasibility study was led by Alcatel ISR, and a mock-up was developed dealing with typical interpretation scenario such as trajectory prediction. Author (revised)

N94-29575# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. for Flight Guidance.
DLR'S ATM DEMONSTRATION PROGRAMME
V. ADAM, E. KLOSTERMANN, and M. SCHUBERT *In* AGARD, Machine Intelligence in Air Traffic Management 12 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04
The Institute for Flight Guidance of DLR is involved in medium and long term research and development of concepts, procedures, functions, and components for a future integrated Air Traffic Management System. The medium term work concentrates on improvements concerning the capacity of Frankfurt airport. This paper describes a planned demonstration program which is designed to prove concepts and tools developed by the Institute in cooperation with the German ATC Authority (DFS) and the operator of Frankfurt airport (FAG) as well as with PHARE. The aim of these experiments is to demonstrate the feasibility and merits of integration of onboard avionics with advanced ATC systems on the ground. For this purpose an Air Traffic Management Demonstrator System will be employed, which comprises an air segment and a ground segment connected via an automatic data link and voice communication. The demonstration program will be performed in several phases comprising simulation runs in an air traffic simulator as well as flight tests with a real aircraft.
Author (revised)

N94-29576# Honeywell, Inc., Minneapolis, MN. Systems and Research Center.
ADVANCED AIR TRAFFIC CONTROL AND FLIGHT MANAGEMENT SYSTEM CONCEPTS
ROBERT L. SCHULTZ *In* AGARD, Machine Intelligence in Air Traffic Management 11 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04
A time-based air traffic control (ATC) system where vehicles are sequenced on desired time of arrival (TOA) has been proposed as one way that might help increase airport capacity. This paper evaluates three time-based ATC system concepts: (1) ground based (computing trajectories on the ground), (2) aircraft based (computing trajectories on the aircraft), and (3) ground and air based (generating parametrized velocity and acceleration profiles on the aircraft and transmitting them to the ground where trajectories are recomputed). The parameters compared are amount of database, complexity of communications, computational requirements, autonomy of aircraft, and similarity to current procedures. The ground-and-air-based approach using parametrized profiles has the best potential for providing a high-landing-rate ATC system with minimal processing and communications requirements. In this approach, ATC assigns time slots at the metering fix based on desired time of arrival (TOA) and range-TOA windows generated on the aircraft. The aircraft sends a simple set of parametrized deceleration and velocity profiles to the ground. The ground processor uses these profiles to generate trajectories and identify conflicts. The ground processor resolves conflicts by examining nearby trajectories using both the sets of parametrized deceleration and velocity profiles and the range-TOA windows. The new horizontal plan and the new profile parameters are sent to the aircraft, where the aircraft flight management system (FMS) regenerates the trajectory and precisely flies it. The advantages of such a system are that it is a natural extension of the current system; it does not require massive ground databases of aircraft thrust, drag and FMS models; it uses a ground processor generating simple models to examine and resolve conflicts; it requires only one air-to-ground interaction; and the aircraft is autonomous. A simulation was used to evaluate the concept. The models used in the simulation are ATC trajectory generator, aircraft FMS, aircraft path controller, and vehicle motion. Multiple-aircraft scenarios, starting in cruise and descent, were examined. Factors examined were separation distances between aircraft on different approach trajectories, accuracy of TOA, and effects of wind-forecast errors on TOA errors. Author

N94-29577# Federal Aviation Administration, Washington, DC.
OPPORTUNITIES FOR INTEGRATING THE AIRCRAFT FMS, AERONAUTICAL OPERATIONAL CONTROL CENTERS, AND FUTURE AIR TRAFFIC MANAGEMENT SYSTEMS IN OCEANIC AIRSPACE
CLYDE MILLER, BILL BLAKE, JOHN SORENSEN, and JOSEPH MILLER *In* AGARD, Machine Intelligence in Air Traffic Management 10 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A02/MF A04
Rapid technological changes are taking place in the aviation system user facilities - both on the aircraft flight deck and at the aeronautical operational control (AOC), or flight dispatch centers. On the flight deck, the flight management system (FMS) is bringing capability for precise three-dimensional guidance, flight path optimization, and speed control to meet required time-of-arrival (RTA) constraints at key route waypoints. This is enhanced by the precision global navigation satellite system (GNSS), use of digital datalink for communications, and automatic dependent surveillance (ADS). At AOC facilities, advancements in flight planning, flight following, weather information and datalink allow the dispatcher greater flight operations management capability over the airline fleet. This is especially significant for oceanic airspace operations. In parallel, the oceanic air traffic management (ATM) system is undergoing an evolution in automation that will enhance the overall aviation system productivity. Much of the information that each of the three system components - flight deck/FMS, AOC, and ATM - have would be very useful to the other two components for flight efficiency and overall productivity enhancements. Worldwide datalink technology will provide a universal and reliable data communication capability between these components to allow this information sharing. This paper discusses the opportunity to integrate the functions of the FMS, AOC, and ATM computers by exploiting the capabilities of worldwide ground and air data link. First, the outstanding needs of both the oceanic airspace user and traffic management provider are stated. Then, the emerging technological capabilities of ATM automation, FMS and AOC are summarized. This is followed by explicit operational applications where the integration of these capabilities can bring incremental benefits to flight efficiency and human productivity. Needs of both the airspace user and air traffic management service provider are addressed. Operations using today's organized oceanic track system as well as the future free route system are discussed. The opportunities for FMS-AOC-ATM integration are illustrated by three scenarios for oceanic operation. These include a mid-oceanic route replanning task to respond to weather change, a passing maneuver to allow more flexibility in flight speed and altitude when flying along a track system, and use of the FMS RTA capability to meet scheduled track entry gate times with precise accuracy.
Author (revised)

N94-29578*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

PROFILE NEGOTIATION: AN AIR/GROUND AUTOMATION INTEGRATION CONCEPT FOR MANAGING ARRIVAL TRAFFIC

DAVID H. WILLIAMS, P. DOUGLAS ARBUCKLE, STEVEN M. GREEN, and WIM DENBRAVEN *In* AGARD, Machine Intelligence in Air Traffic Management 11 p (SEE N94-29558 08-04) Oct. 1993

(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

NASA Ames Research Center and NASA Langley Research Center conducted a joint simulation study to evaluate a profile negotiation process (PNP) between a time-based air traffic control ATC system and an airplane equipped with a four dimensional flight management system (4D FMS). Prototype procedures were developed to support the functional implementation of this process. The PNP was designed to provide an arrival trajectory solution that satisfies the separation requirements of ATC while remaining as close as possible to the airplane's preferred trajectory. The Transport Systems Research Vehicle cockpit simulator was linked in real-time to the Center/TRACON Automation System (CTAS) for the experiment. Approximately 30 hours of simulation testing were conducted over a three week period. Active airline pilot crews and active Center controller teams participated as test subjects. Results from the experiment indicate the potential for successful incorporation of airplane preferred arrival trajectories in the CTAS automation environment. Controllers were able to consistently and effectively negotiate nominally conflict-free trajectories with pilots flying a 4D-FMS-equipped airplane. The negotiated trajectories were substantially closer to the airplane's preference than would have otherwise been possible without the PNP. Airplane fuel savings relative to baseline CTAS were achieved in the test scenarios. The datalink procedures and clearances developed for this experiment, while providing the necessary functionality, were found to be operationally unacceptable to the pilots. Additional pilot control and understanding of the proposed airplane-preferred trajectory and a simplified clearance procedure were cited as necessary for operational implementation of the concept. From the controllers' perspective, the main concerns were the ability of the 4D airplane to accurately track the negotiated trajectory and the workload required to support the PNP as implemented in this study. Author

N94-29579# European Organization for the Safety of Air Navigation, Brussels (Belgium).

AIR-GROUND INTEGRATION OF THE ATM SYSTEM IN PHARE

B. KIRSTETTER and R. D. HUNTER *In* AGARD, Machine Intelligence in Air Traffic Management 11 p (SEE N94-29558 08-04) Oct. 1993

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This paper provides a general introduction into the Programme of Harmonised Air Traffic Management Research in EUROCONTROL (PHARE). It describes the objectives of the research program and addresses the benefits of the integration of the automated systems onboard the aircraft with those of the ATC systems on the ground using a digital air-ground data link. The assumptions on the expected infrastructure and environment are explained and the possible automation and air-ground negotiation strategies discussed. Finally descriptions of the experimental facilities available or under development and of the planned experiments are provided. Author

N94-29580# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. for Flight Guidance.

EXPERIMENTAL FLIGHT MANAGEMENT SYSTEM

V. ADAM, G. INGLE, and R. RAWLINGS *In* AGARD, Machine Intelligence in Air Traffic Management 21 p (SEE N94-29558 08-04) Oct. 1993

(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

The paper reviews the requirements for an Experimental Flight Management System (EFMS) and the methods adopted for its development. The functionality is described and the future application of the system is summarized. Author

N94-29581# National Aerospace Lab., Amsterdam (Netherlands).

THE PHARE ADVANCED TOOLS

HENK A. P. BLOM, GARFIELD DEAN, MARC LEGUILLOU, ERIC PETRE, and UWE VOELCKERS *In* AGARD, Machine Intelligence in Air Traffic Management 8 p (SEE N94-29558 08-04) Oct. 1993

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The Programme for Harmonisation of ATM Research in Eurocontrol (PHARE) has undertaken to perform the required research work necessary for the introduction of advanced ATM. Within this PHARE framework, it is the task of the PHARE Advanced Tools (PAT's) group to develop the appropriate automation and communication tools to support the air traffic controller. Although the principles for computation, prediction and control of air traffic trajectories are well developed, the various future ATM scenarios reflect different views on the way automation and communication technology can best be applied. The consequence of this is that PHARE research has to be directed towards multiple ATM scenarios, and that the PAT's to be developed should be applicable to automation and communication under different ATM scenarios. The paper gives an overview of the approach taken by the PAT's group in facing this challenge. Author

N94-29582# Centre d'Etudes de la Navigation Aerienne, Toulouse (France).

THE COMMON MODULAR SIMULATOR (CMS): AN ARCHITECTURE TEST BED FOR FUTURE ADVANCED ATM SYSTEMS

J. R. VELTEN *In* AGARD, Machine Intelligence in Air Traffic Management 8 p (SEE N94-29558 08-04) Oct. 1993

(AGARD-CP-538) Copyright Avail: CASI HC A02/MF A04

The Common Modular Simulator (CMS) project is part of the Program for Harmonized ATM Research in Eurocontrol (PHARE). The main objective of this project is to provide a common integration environment which shall allow the creation of a homogeneous infrastructure in order to facilitate and harmonize the development as well as the evolution of ATM simulators in the different research establishments. To meet such an ambitious objective, CMS partners have adopted a system architecture based on a client-server model with active servers providing event subscription and event notification mechanisms. The main advantages of such client-server models are to offer a very modular system architecture and to provide, through the associated application programming interface (API), a very powerful mechanism of abstraction. This leads to a very flexible, evolutive, open, scalable and adaptable system. CMS will offer an architecture test bed for future advanced ATM systems. As a consequence, this project should be of great benefit to many other ATM projects. Author (revised)

N94-29583# Eurocontrol Experimental Centre, Bretigny (France).

ARC2000: AUTOMATIC RADAR CONTROL

XAVIER FRON, BERNARD MAUDRY, JEAN-PIERRE NICOLAON, and JEAN-CLAUDE TUMELIN *In* AGARD, Machine Intelligence in Air Traffic Management 14 p (SEE N94-29558 08-04) Oct. 1993

(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

The 'Studies, Tests, and Applied Research' (STAR) program of the EUROCONTROL Agency is addressing several implementation timescales for air traffic management (ATM) systems and procedures. ARC2000 (automatic radar control 2000) is presently the major long-term component of the STAR program, for implementation beyond 2015. ARC2000 is addressing the enroute ATC capacity issue, which is severe in Europe, by investigating the limit case where both major constraints, workload and sectorization, are eliminated. It is often easier to solve a complex problem by first looking at the limit case. ARC2000 could not be implemented as such, but should provide precious information with respect to feasible levels of automation in the long term. There are also significant by-products which will speed up shorter term research. Indeed, ARC2000 provides a 20-30 minute conflict-free planning which is a key feature of the European Air Traffic Management System (EATMS) concept.

Author (revised)

N94-29584# Technische Univ., Brunswick (Germany). Inst. of Flight Guidance and Control.
AUTOMATIC CONTROL STEPS FOR AIRCRAFT TAXI GUIDANCE
KLAUS MOEHLENKAMP and GUNTHER SCHAENZER *In* AGARD, Machine Intelligence in Air Traffic Management 5 p (SEE N94-29558 08-04) Oct. 1993 Sponsored by German Research Society
(AGARD-CP-538) Copyright Avail: CASI HC A01/MF A04

Modern high precision navigation systems based on satellite and inertial navigation provide a positioning accuracy that has never been achieved before, for aircraft enroute as well as during approach and on the airfield. By using such combined accurate positioning systems it is possible to guide aircraft on the ground and to perform automatic taxiing, which further increases the safety of ground operations. Whenever high precision terrestrial navigation is needed, common aeronautical navigation displays are not able to provide the information, which easily can be combined with the pilot's view from the cockpit, to deliver the necessary guidance aid. A flexible map display is desired to be shown in the cockpit. The new taxi guidance system GINaS, presented in this paper, is based on an integrated navigation system (DGPS/INS) and a digital map using only the standard display and navigation hardware of modern commercial aircraft. The system was successfully tested in one of our testbeds, a van. This van can be driven automatically by the system as well as by the pilot using the information of the digital map and a drive-director. The accuracy reaches submeter level. Author (revised)

N94-29585# Marconi Radar Systems Ltd., Chelmsford (England).
AIRSIDE GROUND MOVEMENTS SURVEILLANCE
D. R. CORRALL, A. N. CLARK, and A. G. HILL *In* AGARD, Machine Intelligence in Air Traffic Management 13 p (SEE N94-29558 08-04) Oct. 1993 Sponsored in part by Commission of the European Communities
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

In the modern world there is an increasing need for surveillance, and a consequent need for automatic or semi-automatic methods for processing dynamic input data and presenting it in a form which is useful to the end user. This paper outlines advanced knowledge-based techniques for monitoring such data. The techniques have been applied to airport ground traffic applications and demonstrated in particular on data from actual turn-round scenarios for stand area servicing of an aircraft as observed by a single camera. Results are output in real-time as a status report by an integrated system which is designed to handle the vagaries of real data in respect to incompleteness and uncertainty. The new techniques developed can also be applied to other ground movements surveillance applications which have multiple sensor inputs of the same or different modalities. Author (revised)

N94-29586# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Wessling (Germany). Inst. of Radiofrequency Technology.
A NOVEL NEAR-RANGE RADAR NETWORK FOR AIRPORT SURFACE CONTROL
K.-H. BETHKE, B. ROEDE, M. SCHNEIDER, and A. SCHROTH *In* AGARD, Machine Intelligence in Air Traffic Management 14 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

This contribution describes a radar network for airport surface movement guidance and control. The network comprises several low power radar stations which are organized in modules of four stations each. All antennas are staring and illuminating the area continuously. Moving objects are localized by range profile measurements and a subsequent multilateration. Each module runs autonomously. The module computer at the master station calculates the multilaterations and controls the communication with three slave stations. The measured data from these stations are transferred via the radar transmitters to the master station, while the multilateration and imaging results are sent via data cables to the central computer. There, the information from all modules will be merged and tracks will be constructed; furthermore, a classification process on the basis of the images will be executed. Author (revised)

N94-29587# Federal Aviation Administration, Washington, DC. Research and Development Service.
DEVELOPMENT OF PRECISION RUNWAY MONITOR SYSTEM FOR INCREASING CAPACITY OF PARALLEL RUNWAY OPERATIONS
GENE A. WONG *In* AGARD, Machine Intelligence in Air Traffic Management 12 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

This paper describes the results of a research program to investigate the use of advanced radar, display systems, and controller alert automation aid to increase capacity at airports with closely spaced parallel runways. Analysis has indicated that the runway spacing could be reduced without adversely affecting capacity if a surveillance radar of higher update and accuracy and a high resolution color display system with controller alert automation aid are used. This paper first describes a research program to demonstrate the feasibility of using a precision runway monitor (PRM) system for conducting independent simultaneous approaches to parallel runways spaced at less than 3400 ft (1035 m) apart. A PRM system consists of an improved radar system that provides high azimuth and range accuracy and higher data rates than the current terminal airport surveillance radar (ASR), a processing system that monitors all approaches and generates controller alerts when an aircraft appears to be blundering, and a high resolution color display. Two airports were selected to serve as the demonstration and test facilities of the PRM system. This paper describes the key elements of the demonstration program including test criteria and scenarios, controller and pilot/aircraft response times, and risk analysis. Results of the demonstration program on the feasibility of the 3400 ft runway spacing standards using PRM are presented. Recommendations on radar update rate, accuracy, and display requirements for the PRM system are summarized. This paper also describes the follow-on research activities to investigate further reduction of parallel runway spacing standards to below 3400 ft using the PRM system and advanced navigation and landing systems. Applications and extension of research results to triple and quadruple closely spaced parallel runways are discussed. Author (revised)

N95-18927# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
ON-LINE HANDLING OF AIR TRAFFIC: MANAGEMENT, GUIDANCE AND CONTROL [CONDUITE EN LIGNE DU TRAFIC AERIEN: GESTION, GUIDAGE, AND PILOTAGE]
ANDRE BENOIT, ed., C. GARCIA-AVELLO, J. LEMAITRE, M. PELEGRIN, E. PETRE, and S. SWIERTRA Nov. 1994 220 p Original contains color illustrations
(AGARD-AG-321; ISBN-92-835-0758-4) Copyright Avail: CASI HC A10/MF A03

Following a summary of the activities of the Guidance and Control Panel of AGARD in the field of Air Traffic Handling, this volume constitutes essentially an introduction for those new to the Air Traffic Control Research and Development community, offering, on the one hand, a broad view of the present situation and actual limitations, on the other hand, some precise idea of a long term system objective. It is composed of a preface, a general introduction and ten chapters, each constituting an introduction to the corresponding topics, successively entitled: the air transport system, air traffic complexity, traffic evolution, electronic aids to controllers, arrivals management systems, decision making aids, a look further into the future, towards global optimization, systems evaluation facilities, and the airport of the future. Author

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

N92-23227# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
INTEGRATED DESIGN ANALYSIS AND OPTIMISATION OF AIRCRAFT STRUCTURES
Feb. 1992 212 p The 72nd meeting was held in Bath, England, 29 Apr. - 3 May 1991
(AGARD-R-784; ISBN-92-835-0653-7; AD-A248257) Copyright Avail: CASI HC A10/MF A03

At its 72nd meeting, the Structures and Materials Panel held a workshop to address the role of integrated design analysis and optimization of aircraft structures in order to review and evaluate modern computer codes, and the methodologies for their use. The workshop provided a very useful forum for the exchange of information which is reflected in the papers presented in this report. Among the topics covered are: aerodynamics, aeroelasticity, active control, composite materials, multidisciplinary design and optimization, fin design and optimization, and sensitivity analysis. For individual titles, see N92-23228 through N92-23239.

N92-23228*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A SYSTEM APPROACH TO AIRCRAFT OPTIMIZATION
JAROSLAW SOBIESZCZANSKI-SOBIESKI *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 15 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A03/MF A03

Mutual couplings among the mathematical models of physical phenomenon and parts of a system such as an aircraft complicate the design process because each contemplated design change may have far reaching consequences throughout the system. This paper outlines techniques for computing these influences as system design derivatives useful in both judgmental and formal optimization purposes. The techniques facilitate decomposition of the design process into smaller, more manageable tasks and they form a methodology that can easily fit into existing engineering optimizations and incorporate their design tools. Author

N92-23230*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPLICATION OF MULTIDISCIPLINARY OPTIMIZATION METHODS TO THE DESIGN OF A SUPERSONIC TRANSPORT
J.-F. M. BARTHELEMY (Lockheed Engineering and Sciences Co., Hampton, VA.), P. G. COEN (Lockheed Engineering and Sciences Co., Hampton, VA.), G. A. WRENN (Lockheed Engineering and Sciences Co., Hampton, VA.), M. F. RILEY, A. R. DOVI, and L. E. HALL (Unisys Corp., Hampton, VA.) *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 5 p (SEE N92-23227 14-05) Feb. 1992 Previously announced as N91-23135
(AGARD-R-784) Copyright Avail: CASI HC A01/MF A03

A new optimization based design method is discussed. This method is based on integrating existing disciplinary analysis and sensitivity analysis techniques by means of generalized sensitivity equations. A generic design system implementing this method is described. The system is being used to design the configuration and internal structure of a supersonic transport wing for optimum performance. This problem combines the disciplines of linear aerodynamics, structures, and performance. Initial results which include the disciplines of aerodynamics and structures in a conventional minimum weight design under static aeroelastic constraints are presented. Author

N92-23231# General Dynamics Corp., Fort Worth, TX.
APPLICATION OF ANALYTICAL AND DESIGN TOOLS FOR FIGHTER WING AEROELASTIC TAILORING
JONATHAN D. BOHLMANN, MICHAEL H. LOVE, DANIEL K. BARKER, WILLIAM A. ROGERS, and BETH E. PAUL *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 14 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A03/MF A03

Wing analysis and design studies have been performed for the Validation of Aeroelastic Tailoring (VAT) configuration. The VAT represents a series of static and dynamic wind tunnel tests, performed in the 1970's, to verify the beneficial use of aeroelastic tailoring for fighter aircraft wing design. The VAT provides a useful database for evaluation of various aeroelastic methodologies. Static analysis predictions for ELAPS, a Ritz structural analysis code, are compared to the VAT results, with excellent agreement. ASTROS, a new multidisciplinary finite element optimization code, is also used for static and dynamic analyses of the VAT. The results demonstrate several analysis capabilities of ASTROS. The composite wing skin of the VAT is also optimized by ASTROS for strength and displacement constraints simulating aeroelastic loads. ASTROS was able to design the composite skin to achieve a desired twist and camber deformation behavior. ASTROS is thus a viable tool for aeroelastic tailoring design. Author

N92-23232# Saab-Scania, Linkoeping (Sweden). Aircraft Div.
THE STRUCTURAL OPTIMIZATION SYSTEM OPTSYS: CURRENT STATUS AND APPLICATIONS
TORSTEN BRAMA *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 9 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A02/MF A03

OPTSYS is a modular structural optimization system with well-defined interfaces to finite element (FE) programs and codes for aeroelasticity. A mathematical programming approach is adopted where a sequence of convex approximations of the initial problem is solved, using the method of moving asymptotes (MMA). This approach makes it possible to take all design criteria into account simultaneously. Gradients are calculated semi-analytically. OPTSYS can treat design variables associated to the shape of the structure, the element cross section properties, or the material direction in the case of composite materials. Constraints can be defined on displacement, stress, eigenfrequency, local buckling, flutter, and aileron efficiency. Recent developments have concerned the constraints on dynamic response and acoustics. Other important gradients are: the integration of a preprocessor to define shape variables, the treatment of discrete variables, and the possibility to deal with substructured FE models. The current status of the system capabilities and methods will be discussed and illustrated with applications on aircraft and automotive structures. Author

N92-23233# British Aerospace Public Ltd. Co., Lancashire (England).
APPLICATION OF AN AUTOMATED MULTIDISCIPLINARY ANALYSIS AND OPTIMISATION SYSTEM TO THE DESIGN OF AIRCRAFT STRUCTURES
D. THOMPSON and J. C. AYRES *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 61 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A04/MF A03

Prior to the development of the ECLIPSE system, structural optimization was performed by a combination of software and manual methods. These methods proved their worth by the reduction in costs and improvements in quality resulting from their use. The program used for optimization of structures subject to stiffness criteria became the focus for development of the aeroelastic constraints. This was later extended to incorporate strength constraints, fabrication constraints, and was coupled directly to the NASTRAN analysis system. This process of development continued with the result of the present general resizing, optimization, and post-processing system. This paper describes the application of the system to the optimization of three structures: tail plane, fin/rudder, and foreplane. The emphasis is on the use of the system to optimize for a flutter speed constraint in all three cases. However, in the case of the foreplane, the adaption of the system to include a detail stressing constraint is

illustrated. A brief description of some of the developments proposed for the future is also given. Author

N92-23235# McDonnell Aircraft Co., Saint Louis, MO.
DESIGN OF A FIGHTER AIRCRAFT VERTICAL TAIL ENHANCED BUFFET ENVIRONMENT SURVIVABILITY
DALE M. PITT and ROBERT W. SCANLON *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 6 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A02/MF A03
A method developed for multidisciplinary design of aircraft primary surfaces to include buffet fatigue life improvements is presented. The method is a multistep approach. First, measured buffet pressures are used as the source of excitation. These pressures excite the primary structural modes of the tail and result in high dynamic strains. Second, the Automated Structural Optimization System (ASTROS) multidisciplinary code is used to either raise or lower the primary modal frequencies. Third, a NASTRAN random analysis is used to determine the buffet dynamic strains. Fourth, a subsequent fatigue analysis is used to compute the change in fatigue life. The process was demonstrated on a generic vertical tail. Author

N92-23236# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Airplane Div.
FIRST APPROACH TO AN INTEGRATED FIN DESIGN
G. SCHNEIDER, J. KRAMMER, and H. R. E. M. HOERNLEIN *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 10 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A02/MF A03
The present paper is focused on findings and results of an integrated design optimization study for an aircraft fin. The basic flight mechanics design requirement for a vertical fin is to provide a specified control power inside the whole flight envelope with a minimum weight structure. A method of implicit function theorem has been applied on our MBB fin sample problem. The definition of state variables and independent variables will be discussed in detail. Three basic aerodynamic parameters have been chosen for the sensitivity analysis: taper ratio, aspect ratio, and surface area. This aerodynamic sensitivity analysis has been performed by the finite difference method. The necessary finite element models of the structure have been generated in the same way as the aerodynamic model for the finite difference method. The applied method based on implicit function theorem has proven its capability to provide a transparent method with clear defined discipline interfaces which are essential to monitor a complex system. Author

N92-23237# Alenia, Turin (Italy). Defence Aircraft Group.
A FIN OPTIMISATION STUDY
G. POLLANO *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 10 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A02/MF A03
This paper details the ALENIA activities performed in order to optimize the design of a fin proposed by MBB in an AGARD sub-committee, using the in house optimization program SOS (Structural Optimization System). A series of different optimization studies using stress, efficiency, and flutter constraints was carried out. In addition comparisons between these results and optimizations having frequency separation and displacements as constraints were done. Author

N92-23239# Dassault Espace, Saint-Cloud (France).
STRUCTURAL OPTIMIZATION OF AIRCRAFT PRACTICE AND TRENDS
C. CORNUAULT, C. PETIAU, B. COIFFIER, and A. PARET *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 12 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A03/MF A03
After a general presentation of the CATIA-ELFINI tool, developed by DASSAULT, where computer aided design (CAD), structural analysis, and optimization are fully embedded, we focus on a detailed description of the optimization algorithm. We show the special features of optimization with composite materials. We present: (1) the new organization of design resulting from use of optimization techniques; (2) the application of our optimization techniques on the case of the MBB fin; and (3) techniques neighboring optimization as model adjustment and computation with uncertain data. We conclude by presenting further developments. Author

N92-23950# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON ENGINEERING METHODS IN AERODYNAMIC ANALYSIS AND DESIGN OF AIRCRAFT
Jan. 1992 248 p Special course held in Ankara, Turkey, 6-10 May 1991, in Rhode-Saint-Genese, Belgium, 13-17 May 1991, and in Madrid, Spain, 20-24 May 1991; sponsored in cooperation with the von Karman Inst. for Fluid Dynamics
(AGARD-R-783; ISBN-92-835-0652-9; AD-A247719) Copyright Avail: CASI HC A11/MF A03
Lecture notes for the AGARD Fluid Dynamics Panel Special Course on 'Engineering Methods in Aerodynamic Analysis and Design of Aircraft' have been assembled in this report. Proven engineering methods used during conceptual and preliminary design and development of new aircraft concepts are presented. These methods focus on simple computational procedures for conceptual and preliminary design, low level analysis computer codes, and experimental techniques for aircraft performance predictions. The course was aimed at helping train young engineers to appreciate and work with simple engineering tools to enhance the art of cost effective preliminary design of new aircraft. For individual titles, see N92-23951 through N92-23957.

N92-23951# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.
INTRODUCTION TO SPECIAL COURSE ON ENGINEERING METHODS IN AERODYNAMIC ANALYSIS AND DESIGN OF AIRCRAFT
P. W. SACHER *In* AGARD, Special Course on Engineering Methods in Aerodynamic Analysis and Design of Aircraft 10 p (SEE N92-23950 14-05) Jan. 1992
(AGARD-R-783) Copyright Avail: CASI HC A02/MF A03
There are three major statements that characterize the findings of this special course. First, engineering work in aeronautical analysis and design is traditionally performed both through experiments and through numerical analysis. Second, an interdisciplinary approach is mandatory in conceptual and preliminary design work because although experiments will not be replaced by computational fluid dynamics (CFD), CFD may complement experiments by allowing quicker and more reliable selection of promising configurations. Third, engineering methods are indispensable because: high level CFD analysis is excluded in preliminary design; experimental work may be unavailable for configuration conception; and empirical low level flow code analysis and extrapolation from previous experience is the only logical consequence. H.A.

N92-23952# Dassault Espace, Saint-Cloud (France). Departement d'Aerodynamique Theorique.
COMPUTATIONAL PROCEDURES FOR PRELIMINARY DESIGN
P. PERRIER *In* AGARD, Special Course on Engineering Methods in Aerodynamic Analysis and Design of Aircraft 10 p (SEE N92-23950 14-05) Jan. 1992
(AGARD-R-783) Copyright Avail: CASI HC A02/MF A03
Preliminary design of aircraft has evolved largely over the past ten years. The main origin of the evolution came from the rationalization and broadening of the preliminary emphasis on new project development. The project has to be evaluated more quickly and the capability of a project to meet its requirements must be satisfied. This paper deals specifically with low level computations for preliminary design, and covers such areas as: center of pressure evaluation; lift evaluation; drag evaluation; air-intake integration; afterbody integration; and interactions with non aerodynamic requirements. H.A.

N92-23953# Conceptual Research Corp., Sylmar, CA.
CONFIGURATION DEVELOPMENT
DANIEL P. RAYMER *In* AGARD, Special Course on Engineering Methods in Aerodynamic Analysis and Design of Aircraft 20 p (SEE N92-23950 14-05) Jan. 1992
(AGARD-R-783) Copyright Avail: CASI HC A03/MF A03
Aircraft conceptual design is a complex, multidisciplinary process involving many aspects of engineering. Although this paper focuses on aerodynamic aspects of aircraft design, the overall

configuration of the aircraft must both provide good aerodynamics and reflect a wide variety of other considerations. This paper will discuss the configuration development and its key role in aerodynamic design. Author

N92-23954# Aircraft Research Association Ltd., Bedford (England).
SURVEY OF EXPERIMENTAL TECHNIQUES FOR PERFORMANCE PREDICTION
A. B. HAINES *In* AGARD, Special Course on Engineering Methods in Aerodynamic Analysis and Design of Aircraft 60 p (SEE N92-23950 14-05) Jan. 1992
(AGARD-R-783) Copyright Avail: CASI HC A04/MF A03

This paper reviews the present state of the art in experimental testing in large wind tunnels as a means of predicting aircraft performance. Desirable and attainable standards of accuracy are defined and the paper lists and discusses the factors that contribute to this accuracy. Topics covered include: balances and pressure scanners; quality of tunnel flow; correction of data for wall interference; extrapolation of scale model data to full scale aircraft Reynolds numbers; and propulsion interference effects. Author

N92-23955# National Aerospace Lab., Amsterdam (Netherlands).
PANEL METHODS FOR AERODYNAMIC ANALYSIS AND DESIGN
H. W. M. HOEIJMAKERS *In* AGARD, Special Course on Engineering Methods in Aerodynamic Analysis and Design of Aircraft 47 p (SEE N92-23950 14-05) Jan. 1992
(AGARD-R-783) Copyright Avail: CASI HC A03/MF A03

An overview is presented of several aspects of panel methods used in the aerodynamic analysis and design of aircraft or aircraft components. Panel methods can provide the flow about complex configurations and are routinely used in the analysis of the aerodynamics of realistic aircraft shapes. However, panel methods are based on a mathematical model in which much of the fluid physics is ignored. The report discusses the capabilities and limitations of panel methods, the basic concepts of the panel method, choices that can be made in the basic implementation of the concepts, as well as possible types of boundary conditions that can be utilized to creatively model subsonic and supersonic flow. The discussion also includes aspects of the accuracy of the approximation, consistent formulations, aspects of low and high order panel methods, etc. Also discussed are the computational aspects of panel methods and possible extensions to nonlinear compressible flows, coupling with viscous flow methods, and applications to other flow problems. Author

N92-23957# Grumman Aerospace Corp., Bethpage, NY. Aircraft Systems Div.
AIRCRAFT DRAG ANALYSIS METHODS
CHARLES W. BOPPE *In* AGARD, Special Course on Engineering Methods in Aerodynamic Analysis and Design of Aircraft 50 p (SEE N92-23950 14-05) Jan. 1992
(AGARD-R-783) Copyright Avail: CASI HC A03/MF A03

A collection of aircraft drag analysis methods and drag reduction techniques has been prepared. Pressure, skin friction (viscous), wave (compressibility), lift induced (vortex), interference, throttle dependent, and trim drag source predictions are included. The need to establish a computational drag prediction experience base is emphasized and illustrated. Project type applications are described in which these drag prediction tools have been implemented for drag reduction processes. The paper concludes by summarizing the role played by computerized drag prediction methods in aircraft design programs. Author

N92-27870# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
TECHNICAL EVALUATION REPORT ON THE FLIGHT MECHANICS PANEL SYMPOSIUM ON FLYING QUALITIES
HAROLD ANDREWS (Aviation Systems and Research, Arlington, VA.) Apr. 1992 22 p
(AGARD-AR-311; ISBN-92-835-0665-0) Copyright Avail: CASI HC A03/MF A01

The validity of constraining the responses of today's control dominant aircraft to conform to the classic flying qualities criteria derived from stability dominant aircraft experience has been an issue for many years. The introduction of full time visual scene enhancement with sensor fusion, and computer generated/interpreted night scenes, and the use of integrated flight and propulsion control schemes and direct force controllers have expanded flight envelopes, reduced drag, increased maneuverability, provided the framework for practical gust alleviation and active flutter suppression, and provided flexibility for fault-tolerant, damage-adaptive flight controls. However, the updating of flying qualities criteria has in general not kept pace with these technological changes. The Flight Mechanics Panel of AGARD therefore decided to organize a Symposium to review flying qualities issues today, and to report progress towards their resolution. The topic areas included: Flying Qualities Experiences on Contemporary Aircraft; Application of Flying Qualities Specifications; Flying Qualities Research and Flying Qualities at High Incidence. This Technical Evaluation Report evaluates the presentations and discussions in each session, draws relevant conclusions and makes recommendations for future activities in this area. The papers presented at this Symposium are published as AGARD Conference Proceedings 508. Author

N92-27890# Alenia, Turin (Italy). Div. Avionica ed Apparati Speciali.
AUTOMATED TARGET TRACKING AND LOCATION TECHNIQUES APPLIED TO OPTICAL PAYLOADS ON REMOTELY PILOTED VEHICLES
MARIO AUDENINO, ANTONIO GAGLIO, and PAOLO FAGGION *In* AGARD, Air Vehicle Mission Control and Management 14 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

The ALENIA Mini-Remotely Piloted Vehicle.(RPV) System has the capability to perform different missions; one of the most useful missions is to provide real-time target acquisition (detection, recognition, identification and location) from the battlefield. When the target has been identified, the Mini RPV System within the GCS processes data arriving from the air vehicle and with the aid of digital terrain maps gives the target location by determining geographical coordinates and altitude. Target location is calculated using the vector from the air vehicle to the target and the RPV present position. The RPV to target vector information relative to air vehicle body coordinate is derived from sensor LOS data acquired using a stabilized platform. This platform permits target tracking irrespective of air vehicle motion. With present on-board electronics and digital terrain maps, the target location accuracy is approximately 50 meters CEP. Author

N92-28468# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
AIRCRAFT SHIP OPERATIONS [LE COUPLE AERONEF-NAVIRE DANS LES OPERATIONS]
J. G. HOEG (Naval Air Test Center, Patuxent River, MD.) Apr. 1992 13 p Presented at the Flight Mechanics Panel Symposium, Seville, Spain, 20-23 May 1991
(AGARD-AR-312; ISBN-92-835-0668-5; AD-A253805) Copyright Avail: CASI HC A03/MF A01

Worldwide interest in the use of shipborne aircraft as a major weapons system is very broad. Many NATO countries operate fixed wing aircraft from ships. Additionally, the use of ships as helicopter platforms is extensive in the NATO community and brings another important dimension to the aircraft/ship interface issue. Thus, it seemed that both fixed and rotary wing aviation deserved equal billing in the Aircraft/Ship Interface Symposium which is the subject of this Technical Evaluation Report. The Symposium contained twenty-five presentations grouped under the following topics: Keynote Addresses; Ship Environment; Guidance, Controls, and Displays; Flight Test and Simulation Techniques; Launch, Recovery, and Handling Systems Development; and Operational Views and Future Developments. Author

N92-28469# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
INTEGRATED DESIGN ANALYSIS AND OPTIMISATION OF AIRCRAFT STRUCTURES [L'ANALYSE INTEGRALE DE LA CONCEPTION ET L'OPTIMISATION DES STRUCTURES DES AERONEFS]
May 1992 88 p Lectures held in Pasadena, CA, 8-9 Jun. 1992, in Lisbon, Portugal, 22-23 Jun. 1992, and in London, England, 25-26 Jun. 1992
(AGARD-LS-186; ISBN-92-835-0675-8; AD-A255373) Copyright Avail: CASI HC A05/MF A01
There is a lack of precise information on the effectiveness of specific methods in generating optimum designs for realistic aircraft structures. In this situation it is difficult for designers to make decisions on which systems to employ for a given design problem and which developments to pursue. Thus, it is necessary for designers to be aware of the relative merits of the different methods currently used for the design optimization of advanced aircraft. This lecture series covers the methods available for the computer based design analysis and design optimization of aircraft structures. The lecture series deals with the principles and practices adopted to integrate the various factors which are considered in the design of advanced aircraft. These factors include: structural shape, aerodynamics, active control technology, and aircraft performance. For individual titles, see N92-28470 through N92-28474.

N92-28470# Cranfield Inst. of Tech., Bedford (England). Dept. of Aerospace Science.
FUNDAMENTALS OF STRUCTURAL OPTIMISATION
A. J. MORRIS *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 13 p (SEE N92-28469 19-05) May 1992
(AGARD-LS-186) Copyright Avail: CASI HC A03/MF A01
Structural optimization is concerned with the computerized automatic design of structures which are optimum with respect to some major design parameter. In the aircraft industry this parameter has usually been structural weight, though cost, performance, or other factors are now being considered. The general problem which is characterized here remains unchanged so that the basic nature of the optimization problem is the same for all applications. Also the structural optimization problem is always characterized by the finite element method (FEM). The use and application of these methods to computer aided design (CAD) requires some understanding of the underlying mathematical principles. It is shown that this process of developing solution methods use the optimization criteria as the basis for creating the up-date formulae which are the solution algorithm drivers. H.A.

N92-28471# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.
PRACTICAL ARCHITECTURE OF DESIGN OPTIMISATION SOFTWARE FOR AIRCRAFT STRUCTURES TAKING THE MBB-LAGRANGE CODE AS AN EXAMPLE
J. KRAMMER *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 16 p (SEE N92-28469 19-05) May 1992
(AGARD-LS-186) Copyright Avail: CASI HC A03/MF A01
The structural optimisation system MBB-Lagrange allows the optimization of homogeneous isotropic, orthotropic or anisotropic structures as well as fiber reinforced materials. With the simultaneous consideration of different requirements in the design of aircraft structures it is possible to reduce the number of iteration steps between design, analysis and manufacturing. Based on finite element methods for structures and panel methods for aerodynamics, the analysis with sensitivity includes modules for static, buckling, dynamic, static aeroelastic and flutter calculations. The optimization algorithms consists of mathematical programming methods and an optimization and analysis/sensitivity is the optimization model which leads to a very modular architecture. Typical application examples show the power and generality of the approach. Author

N92-28472# Dassault (E. M.) Co., Saint-Cloud (France).
STRUCTURAL OPTIMIZATION OF AIRCRAFT
C. CORNUAULT and C. PETIAU *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 17 p (SEE N92-28469 19-05) May 1992
(AGARD-LS-186) Copyright Avail: CASI HC A03/MF A01
A general survey of Dassault experience and knowledge on Aircraft Design with Optimization Methods is depicted. This survey results from compiling the developments and the results already worked out and already presented in several papers. Part 1 gives a detailed description of the methodology. The special features of optimization with composite materials are shown. The organization of design resulting from use of optimization techniques is described and techniques neighboring optimization as model adjustment are reviewed, as well as further developments. Part 2 illustrates this methodology by an actual case study of an aircraft design by Dassault-Aviation with relevant examples of structural and aeroelastic optimization on carbon structures of a wing and a fin. Author

N92-28473*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MULTIDISCIPLINARY DESIGN AND OPTIMIZATION
JAROSLAW SOBIESZCZANSKI-SOBIESKI *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 15 p (SEE N92-28469 19-05) May 1992 Presented as A System Approach to Aircraft Optimization, Paper No. 2 at the AGARD Workshop on Integrated Design Analysis and Optimization of Aircraft Structures, Bath, England, 1-2 May 1991
(AGARD-LS-186; AGARD-PAPER-2) Copyright Avail: CASI HC A03/MF A01
Mutual couplings among the mathematical models of physical phenomena and parts of a system such as an aircraft complicate the design process because each contemplated design change may have a far reaching consequence throughout the system. This paper outlines techniques for computing these influences as system design derivatives useful to both judgmental and formal optimization purposes. The techniques facilitate decomposition of the design process into smaller, more manageable tasks and they form a methodology that can easily fit into existing engineering optimizations and incorporate their design tools. Author

N92-28474# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.
MATHEMATICAL OPTIMIZATION: A POWERFUL TOOL FOR AIRCRAFT DESIGN
OTTO SENSBURG *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 19 p (SEE N92-28469 19-05) May 1992
(AGARD-LS-186) Copyright Avail: CASI HC A03/MF A01
Formal mathematical optimization methods have been developed during the past 10 to 15 years for the structural design of aircraft. Together with reliable analysis programs like finite element methods they provide powerful tools for the structural design. They are efficient in at least two ways: (1) producing designs that meet all specified requirements at minimum weight in one step; and (2) relieving the engineer from a time consuming search for modifications that give better results, they allow more creative design modifications. MBB has developed a powerful optimization code called MBB-Lagrange which uses mathematical programming and gradients to fulfill different constraints simultaneously. Some examples depicting the successful application of the MBB-LAGRANGE code are presented. Also results of other optimization codes are shown. The paper closes with an outlook on how the optimization problem could be enlarged to include the shape and size of airplanes. Author

N92-28531# Royal Aerospace Establishment, Bedford (England). FMS Div.
VALIDATION OF SIMULATION SYSTEMS FOR AIRCRAFT ACCEPTANCE TESTING
A. A. WOODFIELD *In* AGARD, Piloted Simulation Effectiveness 4 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A01/MF A03
There is currently a limited role for simulation in flight clearance of sub-systems in civil aircraft. However, the extensive use of simulation for manned space vehicle clearance shows the potential for simulation to join other rigs in flight clearance. There is a

serious risk that simulation could prove inadequate if there is no systematic validation program. Simulation is a complex integration of models of vehicles and the environment, physical sensation devices and the pilot. Any of these can be modified to compensate for inadequacies in parts of the simulation. This can be acceptable for training simulators but is not acceptable for clearance activities because the influence of such modifications cannot be predicted in situations that are not going to be tested in flight. These issues are discussed. Author

N93-13207# Deutsche Airbus G.m.b.H., Bremen (Germany).
RECENT DEVELOPMENTS IN LOW-SPEED TPS-TESTING FOR ENGINE INTEGRATION DRAG AND INSTALLED THRUST REVERSR SIMULATION
W. BURGSMUELLER, C. CASTAN (Aerospatiale, Toulouse, France), J. W. KOOI (Duits-Nederlandse Windtunnel, North East Polder.), and J. P. BECLE (Office National d'Etudes et de Recherches Aerospatiales, Paris, France) *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 15 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

In accordance with the steady increase in bypass ratio and hence fan nacelle diameter of engines for modern transport aircraft, also the investigation of engine-airframe interference effects is of increasing importance. This covers not only the interferences between the wing and nacelle plus pylon bodies, but also the effects due to the presence of the engine jet flow field. In the low speed range of an aircraft, i.e., take-off, second segment climb, landing and roll out with thrust reversing, the jet interference investigations require wind tunnels with special high quality equipment, highly instrumented models with engine simulators and test setups outside the tunnel for special investigations. Concerning the different possibilities for engine simulation, the use of turbine-powered-simulators (TPS) has proven as the best and most flexible instrument. The paper presented here describes the technical progress made in the last years in testing techniques, based on close cooperation between Deutsche Airbus, Aerospatiale, DNW and ONERA. Further, a survey about the possible applications for low speed jet interference testing is given, mainly based on the Airbus A340 development program. Finally, some of these recent test results concerning performances and understanding of the aerodynamic and thermodynamic phenomena, especially concerning second segment climb jet interference, thrust reverser efficiency and plume reingestion effects are shown and discussed. It can be summarized, that a high level of technical test standard has been achieved and this together with a better understanding of the flow phenomena gives a viable basis for the integration of the coming generations of aircraft and engines. Author

N93-13208# Fokker B.V., Schipol-Oost (Netherlands). Aerodynamics and Aeroelasticity Dept.
AERODYNAMIC INTEGRATION OF THRUST REVERSERS ON THE FOKKER 100
J. VANHENGST *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 9 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A02/MF A04

The Fokker 100 is a twin engined T-tailed aircraft developed as a short to medium haul passenger and cargo transport. The engines are located on the aft fuselage. The development of thrust reversers on this type of aircraft was accomplished through different types of wind tunnel model tests and full scale tests. Model tests on an isolated exhaust configuration, scale 1:5, were conducted at Fluidyne in order to establish nozzle suppression and thrust reverser efficiency and side plume effects. Effects on directional and longitudinal stability characteristics were investigated by model tests on a complete mode, scale 1:12, in the LST of NLR. Reingestion tests were performed on the same complete model in the RR low speed facility at Hucknall. Attached photographs show the model in the NLR and RR facilities. This paper discusses the integration process, showing test results from wind tunnel model tests as well as full scale boiler plate and flight tests. A successful means to control side plume effects on the directional stability and a configuration change to suppress induced reverse plume empennage buffet is also discussed. Author

N93-13212# Societe Nationale d'Etudes et de Construction de Moteurs Aeronautiques, Moissy-Cramayel (France).
FLIGHT ANALYSIS OF AIR INTAKE/ENGINE COMPATIBILITY [ANALYSE EN VOL DE LA COMPATIBILITE ENTREE D'AIR-MOTEUR]
H. JOUBERT and J. L. EYRAUD *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 12 p (SEE N93-13199 03-34) Sep. 1992 In FRENCH
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

Performance improvement of the combat aircraft/engine unit rests on the optimization of intake/engine compatibility. This optimization requires specific flight tests in which the loss of the pumping margin of the compressors due to distortion is determined. The general methodology for the intake/engine compatibility analysis is described from the first wind tunnel tests to the flight tests. In order to determine the loss of the pumping margin due to the distortion of the air intake, an extensive instrumentation set was installed on the Mirage 2000 (Dassault Aviation) aircraft equipped with the M53-P2 (SNECMA) engine. The test procedures as well as the processing of the nonstationary signals are described. The correlations binding the nonstationary coefficients of distortion to the loss of pumping margin of the low pressure compressor are presented. It is shown that a correlation to only one parameter makes it possible to reach an accuracy of plus or minus 2 percent. On the other hand, the use of a correlation of two parameters (circumferential and radial) makes it possible to reduce the precision to plus or minus 1 percent. The use of an engine test stand in an altitude chamber with channels simulating nonstationary distortion makes it possible to reproduce in a satisfactory way the phenomena observed in flight and, in particular, to measure values of sensitivity to the distortion similar to the values obtained in flight. This method makes it possible to improve the optimization of the engine while reducing the number of flight tests. Transl. by FLS

N93-13219# Aircraft Research Association Ltd., Bedford (England).
SOME ASPECTS OF INTAKE DESIGN, PERFORMANCE AND INTEGRATION WITH THE AIRFRAME
E. L. GOLDSMITH *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 19 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

A selection of topics has been made from the state of the art review in the Fluid Dynamics Panel Working Group 13 Report on Intakes for High Speed Vehicles. The first topic is a brief account of results from a program of research on internal and external flow in pitot intakes conducted in the UK over the period 1978-88. The main topic is that of intake airframe integration and is illustrated by examples from systematic work done in the USA and Europe on agile strike fighters and multi-intake missiles. Author

N93-13224# Wright Lab., Wright-Patterson AFB, OH.
SURVEY ON TECHNIQUES USED IN AERODYNAMIC NOZZLE/AIRFRAME INTEGRATION
DOUGLAS L. BOWERS and JAMES A. LAUGHREY *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 11 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

Building on a survey conducted in 1984 of the state-of-the-art of experimental and computational tools used to evaluate aerodynamic nozzle/airframe integration, this paper critically re-assesses these techniques in 1991. For experimental techniques, there have not been significant developments in the intervening seven years, and these mature techniques still serve the design engineer well. On the computational side, Euler techniques are now being applied as design tools in nozzle problems where there are not strong viscous interactions. Computation of the viscous regions, especially the nozzle boattail, with Navier-Stokes algorithms is still lacking. Author

N93-13228# Wright Lab., Wright-Patterson AFB, OH.
PROPULSION INTEGRATION RESULTS OF THE STOL AND MANEUVER TECHNOLOGY DEMONSTRATOR
J. A. LAUGHREY and D. J. MOORHOUSE *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 12 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

The STOL and Maneuver Technology Demonstrator program has achieved its original goals established to demonstrate the benefits of thrust vectoring and reversing on a fighter aircraft. It has been shown that thrust vectoring will enhance up-and-away aircraft maneuverability at low speeds and can be used to improve tracking and capture tasks plus contribute significantly to improve takeoff performance and rough or damaged runway operations. Thrust reversing has been shown to permit quicker changes in energy states that could provide an advantage in tactical arena and can greatly reduce landing distances. It was also demonstrated that an integrated flight and propulsion control system that incorporates the appropriate control laws can significantly simplify pilot workload during all vectoring and reversing operations, including the approach, landing, and stopping tasks. Results of this program are being used to transition these proven technologies into future fighter systems. Author

N93-17618# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Aircraft Div.
AERODYNAMIC ENGINE/AIRFRAME INTEGRATION FOR HIGH PERFORMANCE AIRCRAFT AND MISSILES
P. W. SACHER and W. SCHMIDT *In* AGARD, Airbreathing Propulsion for Missiles and Projectiles 21 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

This paper is a FDP contribution to the 79th symposium on 'Airbreathing Propulsion for Missiles and Projectiles' being held from 11-15 May 1992 in St. Medard-en-Jalles, Bordeaux, France. It presents an overview of the main findings of the last FDP meeting during 7-15 Oct. 1991 in Fort Worth, TX, USA on the subject of the title of this review paper. The meeting was structured in six sessions, one of them having been organized and chaired in form of an invited session by PEP contributions. Each session will be reviewed separately in this paper and conclusions (in some cases recommendations for future AGARD activities) are made based on the major outcome of the sessions including contributions and comments from the auditorium after the presentations or from the closing Round-Table-Discussion at the end of the meeting. It has been clearly demonstrated that the subject of the symposium is a highly interdisciplinary effort, which overlaps the terms of reference of both AGARD Panels, FDP and PEP to a large extent. This is specifically true for major components of the propulsion system like the air intake and the nozzle. Both experimental and computational techniques for analysis and design used during the engine/airframe integration for all kinds of flight vehicles have been reported. Author

N93-19901# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
FLIGHT TESTING [LES ESSAIS EN VOL]
Oct. 1992 405 p In ENGLISH and FRENCH Symposium held in Chania, Greece, 11-14 May 1992
(AGARD-CP-519; ISBN-92-835-0688-X) Copyright Avail: CASI HC A18/MF A04

It is considered by the Flight Mechanics Panel of AGARD as vitally important that the NATO flight test community meet regularly so that new techniques for flight test, instrumentation and data analysis and lessons learned from past and on-going programs be disseminated to ensure that safe efficient cost-effective and timely testing is accomplished. There are many new systems being tested or planned for testing in the near future. These include programmable signal processor radars, integrated flight, fire and propulsion control systems, thrust vectoring, low observable technologies, multifunction pilot displays and multisensor integration. Acquisition and processing of large quantities of avionics multiplex data are challenges that must be met. There is a need for greater use of simulators and other hardware-in-the-loop ground test facilities. For individual titles, see N93-19902 through N93-19930.

N93-19902# Department of Defense, Washington, DC. Testing and Evaluation Office.
TEST AND EVALUATION CHALLENGES IN THE NINETIES
CHARLES E. ADOLPH *In* AGARD, Flight Testing 6 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A02/MF A04

The Flight Mechanics Panel devotes a symposium to flight testing every 3-4 years. Since the Warsaw Pact is gone, the Soviet Union no longer exists, and Germany is reunited, the United States has been involved in two limited conflicts. We are drawing down the Defense establishment in the United States to reflect the new world situation. I want to briefly discuss the Department of Defense plans for restructuring, because they have a major impact on the weapon system acquisition and test community. I.I.C.

N93-19903# Aerospatiale, Toulouse (France).
FLIGHT TESTS OF THE TRANSPORT AIRCRAFT VIEWED FROM THE INDUSTRIAL STANDPOINT [LES ESSAIS EN VOL DES AVIONS DE TRANSPORT VUS SOUS LA PERSPECTIVE INDUSTRIELLE]
G. DEFER and G. DESTARAC *In* AGARD, Flight Testing 6 p (SEE N93-19901 06-05) Oct. 1992 In FRENCH
(AGARD-CP-519) Copyright Avail: CASI HC A02/MF A04

The development of new aircraft requires very heavy investments. Among these investments are the flight tests. Even if the flight tests correspond, on the average of 8 percent of the development cost, an economical approach should be taken. This is what Aerospatiale tried to do for nearly 3 decades on the main base of Toulouse Glagnac. The present development situation is described. Author

N93-19904*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
LESSONS LEARNED FROM AN HISTORICAL LOOK AT FLIGHT TESTING
SETH B. ANDERSON *In* AGARD, Flight Testing 11 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

A brief historical review of accidents was made to examine lessons learned in flight testing with major emphasis on human factors limitations. The results of this survey show undeniably that new aircraft and new pilots are not immune to old problems. Of three related human factors limitations, pilot skill frequently showed up as the primary factor responsible for accidents due to inadequate training (or proficiency) to handle an unexpected situation. A primary contributing factor was unsatisfactory aircraft handling qualities which increased pilot work load and therefore were less forgiving to 'pilot error,' particularly when flown in a stressful situation at the extremes of the flight envelope. Historically, pilot induced oscillation (PIO) has persisted as a major control problem particularly in first-flight operation. Deliberate errors involving a conscious decision to 'take a chance' by flying an aircraft with known deficiencies occurred more frequently in early times. Finally, inadvertent errors involving forgetfulness, indecision, and confusion are occurring more frequently with the current trend toward automated computerized controlled cockpits. Author

N93-19905# Dassault-Breguet Aviation, Saint-Cloud (France).
RAFALE: PROGRESS OF THE PROGRAM [RAFALE: ADVANCEMENT DU PROGRAMME]
PATRICK CASTAGNOS *In* AGARD, Flight Testing 10 p (SEE N93-19901 06-05) Oct. 1992 In FRENCH
(AGARD-CP-519) Copyright Avail: CASI HC A02/MF A04

The RAFALE C01 carried out its first flight on May 19, 1991. This event demonstrated the leading position taken on the RAFALE program, which was launched 3 years earlier by the French government and primarily designed to equip the French air forces and naval aviation as of 1997. Author

N93-19906# Lockheed Advanced Development Co., Sunland, CA.
YF-22A PROTOTYPE ADVANCED TACTICAL FIGHTER DEMONSTRATION/VALIDATION FLIGHT TEST PROGRAM OVERVIEW
RICHARD ABRAMS *In* AGARD, Flight Testing 21 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

The Lockheed Aeronautical Systems Company, teamed with the General Dynamics Fort Worth Division and Boeing Military Airplanes Company, designed, built and flight tested two YF-22A Advanced Tactical Fighter (ATF) prototypes which were powered by new prototype high thrust-to-weight ratio engines. The YF-22A design optimized the blend of low observability, maneuverability and supersonic performance. These design goals were achieved with the incorporation of many new and innovative technologies including thrust vectoring, integrated flight and propulsion control, internal weapons carriage, and composite materials. An advanced cockpit with colored liquid crystal displays, finger-on-glass controls and advanced avionics architecture was also incorporated in the prototypes. The YF-22A Demonstration/Validation (Dem/Val) flight test program was completed on the 28th of December 1990. Seventy-four flights for a total of 91.6 flight hours were accumulated on both prototypes. The first flight of YF-22A No. 1 was made on 29 September 1990, the second prototype flew on 30 October 1990. The primary objective of the Dem/Val flight test program was to demonstrate the airplane's capabilities. This approach, which prioritized the use of the aircraft as demonstrators over their use as development tools, was considered to be the most efficient method of generating the test data required for the Engineering and Manufacturing Development (EMD) proposal. The purpose of this paper is to briefly describe some of the YF-22A's unique design features and the Dem/Val flight test program. Author

N93-19907# Aeronautica Macchi S.p.A., Varese (Italy).
MB-339: THE ROLE OF FLIGHT TESTING IN THE EVOLUTION PHASE OF A PROVEN AIRCRAFT
~~P. APOLLONIO, S. PEYRONEL, E. TOSO, and E. TROMBETTA~~
In AGARD, Flight Testing 22 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

The MB-339 is a proven jet trainer developed by Aermacchi in the late '70s, operational within the Air Forces of 8 Countries. In order to keep pace with the increasing needs in the training syllabus mainly related to the systems management, Aermacchi launched the development of the 'C' version, equipped with an integrated, digital NAV-ATTACK system. The development program was mainly company-funded, so that a 'modular' approach to the test was adopted in order to allow the validation of the design and the achievement of operational clearance, in accordance with the needs of freezing HW/SW configuration as soon as possible on one side and to maximize the results of the agreed flight test programme on the other. A further significant activity carried out in the same time has been the ASC (Airborne Strain Counter) development, a system designed in order to satisfy the need of the Italian National Aerobatic Team for an adequate monitoring of the structural fatigue accumulated on their aircraft. Finally, Aermacchi (with Oto Melara under a contract with the Italian Ministry of Defense) is completing the program for the integration on the MB-339 of an antiship missile aimed to demonstrate the operational capability and flexibility of the aircraft. Aermacchi's particular approach to flight tests, consisting in having the flight test engineering function distributed within all technical department branches and therefore eliminating the separation between design and test engineering, provided positive results in the whole development process. Purpose of the paper is to present the characteristics of the test program carried out, to highlight the factors that allowed the full achievement of the objectives and to provide an outlook of the characteristics of the aircraft systems. Author

N93-19908# National Aero-Space Plane Joint Program Office, Wright-Patterson AFB, OH.
THE NATIONAL AERO-SPACE PLANE PROGRAM: A REVOLUTIONARY CONCEPT
ROBERT R. BARTHELEMY *In* AGARD, Flight Testing 9 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A02/MF A04

NASP - The National Aero-Space Plane - is a look into the future. It is a vision of the ultimate airplane, one capable of flying at speeds greater than 17,000 miles per hour, 25 times the speed of sound. It is the attainment of a vehicle that can routinely fly from earth to space and back, from conventional airfields, in affordable ways. It is the achievement of major technological breakthroughs that will have an enormous impact on the future growth of this nation. Most of all, it is a projection of America at its best, at its boldest, at its most creative. NASP is more than a national aircraft development program, more than the synergy of revolutionary technologies, more than a capability that may change the way we move through the world and the aerospace around it. NASP is a revolutionary technical, managerial, and programmatic concept; it is a possibility of what can be in America. The NASP program can be described in a number of ways: technological, programmatic, utilitarian, and conceptual. In each case, NASP has departed from the traditional evolutionary path. In order to achieve the vision of NASP, innovative and revolutionary approaches are required. The technical challenges require the synergism of several major technology breakthroughs. The programmatic challenges require a fundamental change in the development, management, and implementation of this strategic, high-tech program. The utility challenge requires a transformation of our thinking about aeronautical and aerospace systems. The conceptual challenge requires a paradigm shift in national planning, collaboration, and commitment. Each of these challenges, and the NASP response to them, is explored in the following pages. Author

N93-19909# Army Aviation Systems Command, Moffett Field, CA.
GENERATION OF HELICOPTER ROLL AXIS BANDWIDTH DATA THROUGH GROUND-BASED AND IN-FLIGHT SIMULATION
HEINZ-JUERGEN PAUSDER (Deutsche Forschungsanstalt fuer ~~Luft- und Raumfahrt, Berlin, Germany) and CHRIS L. BLANKEN~~
In AGARD, Flight Testing 15 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

N93-19910# Alenia, Turin (Italy).
AM-X HIGH ANGLE OF ATTACK FLIGHT TEST EXPERIENCE (SINGLE AND TWO SEAT VERSIONS)
G. MENSO, B. MARCHETTO, and E. MONFORTE *In* AGARD, Flight Testing 13 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

This paper describes the activities carried out at the ALENIA Flight Test Center in order to investigate the high angle of attack characteristics of the AM-X. Before starting with the flight tests, vertical wind tunnel and rotary balance facilities have been used to collect all the information on aircraft behavior at stall, behind stall and in developed spin, in order to efficiently and safely approach the flight test activity. Flight tests have been tailored for the primary role of this A/C: the ground attack. Flight trails were firstly devoted to the combat configuration to assess the A/C capability to perform safe defensive maneuvers at high angle of attack. Then, a number of external stores key-configurations were tested to verify the A/C capability to safely perform vigorous maneuvers as required for such a light attack aircraft. Finally the twin seater behavior, clean and with stores, has been investigated. Analysis of the tests results provided the confidence for further investigating on developed spin characteristics and for the A/C qualification to intentional departure in a defined envelope for training purposes. Author

N93-19911# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).
X-31A HIGH ANGLE OF ATTACK AND INITIAL POST STALL FLIGHT TESTING
P. HUBER and H. GALLEITHNER *In* AGARD, Flight Testing 11 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04
In November 1991 after about one year of successful conventional flight testing, the X-31A research aircraft no. 2 was taken to more than 30 degrees angle of attack for the first time. Since then a maximum angle of attack of about 53 degrees in 1-g flight has been achieved. This is the first time a dedicated post stall aircraft design has entered flight test beyond stall angles of attack. This paper summarizes descriptions of the control law characteristics of the X-31A and describes the flight test approach followed to safely expand and explore the high angle of attack and post stall flight regime. Furthermore, preliminary handling qualities test results obtained from the initial post stall envelope expansion are presented. Author

N93-19912# Dassault-Breguet Aviation, Saint-Cloud (France).
METHOD FOR DEVELOPING THE RAFALE FLIGHT CONTROL SYSTEM [METHODE DE DEVELOPPEMENT DU SYSTEME DE CONTROLE DU VOL DU RAFALE]
P. BOURDAIS and R. L. DURAND *In* AGARD, Flight Testing 13 p (SEE N93-19901 06-05) Oct. 1992 In FRENCH
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04
The sequences are presented of the different tasks implemented for the development of the RAFALE SCV (Flight Control Program), and its design for its flight qualification, by giving details in particular of the essential points, namely the activities associated with the aerodynamic and structural modeling of the aircraft. The functional studies aim at defining the control laws, validating the SCV and its equipment in a real time flight controlled simulation environment, analyzing and processing the flight tests and incorporating these results in the adjustment phase of the SCV. Author

N93-19913# Instituto Superior Tecnico, Lisbon (Portugal).
ON AUTOMATED ANALYSIS OF FLIGHT TEST DATA
L. M. B. C. CAMPOS (Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau, Germany), A. A. FONSECA, and A. M. G. CARDOSO (Portuguese Air Force Academy, Granja do Marques.) *In* AGARD, Flight Testing 17 p (SEE N93-19901 06-05) Oct. 1992
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The automated analysis of flight test data depends on an indicator of when an atmospheric event, or flight maneuver, starts and ends. We use as indicator the disturbance intensity, which is defined as the relative lift change, and can be related either to aerodynamic or flight dynamical parameters. A number of flight test data records, obtained using the Portuguese CASA 212 Aviocar flight test aircraft, are analyzed to show how the start and end of a maneuver are signaled by the disturbance intensity. The latter is a possible objective measure, for a proposed scale of passenger/crew comfort, somewhat analogous to the Cooper-Harper handling qualities scale. Author

N93-19914# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Berlin (Germany).
SYSTEM IDENTIFICATION FOR X-31A PROJECT SUPPORT: LESSONS LEARNED SO FAR
S. WEISS, E. PLAETSCHKE, D. ROHLF, and H. GALLEITHNER (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen, Germany) *In* AGARD, Flight Testing 11 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04
Flight testing of the X-31A post-stall experimental aircraft started in October 1990. Within the international 'Combined X-31A Flight Test Team', DLR contributes its system identification experience and capabilities for the determination of aerodynamic parameters from flight test data. The paper presents a brief description of the hard- and software for flight test data evaluation applied by DLR to support the X-31A project on-site. It describes the different steps of the data reduction and the models used for system identification. Selected results which were achieved mainly on the basis of data from flight test conducted for handling qualities investigations are shown and compared to wind tunnel predictions. The paper discusses the aspects of on-site system identification for flight test support, including the difficulties arising from working on a low-cost program. It is based on the experience made during the initial envelope expansion of the X-31A. Author

N93-19916*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
OVERVIEW OF THE NASA DRYDEN FLIGHT RESEARCH FACILITY AERONAUTICAL FLIGHT PROJECTS TESTING
ROBERT R. MEYER, JR. *In* AGARD, Flight Testing 17 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04
Several principal aeronautics flight projects of the NASA Dryden Flight Research Facility are discussed. Key vehicle technology areas from a wide range of flight vehicles are highlighted. These areas include flight research data obtained for ground facility and computation correlation, applied research in areas not well suited to ground facilities (wind tunnels), and concept demonstration. Author

N93-19919# National Aerospace Lab., Amsterdam (Netherlands).
FLIGHT TESTING OF GPS AND GPS-AIDED SYSTEMS
O. B. M. PIETERSEN, M. A. G. PETERS, and N. VANDRIEL *In* AGARD, Flight Testing 11 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04
In three years of GPS (Global Positioning System) testing by the National Aerospace Laboratory NLR in the Netherlands, the complexity of the systems evaluated has increased considerably, from a stand-alone GPS receiver to an integrated navigation system in which GPS is one of the sensors. This paper describes in short a number of flight test programs carried out by NLR, namely (1) trials to investigate the suitability of differential GPS for precision approaches; (2) trials to determine the advantages of aiding a GPS receiver by INS (Inertial Navigation System) and of the use of null-steering antennas; and (3) trials to evaluate an in-house developed navigation filter in which three navigation sensors, GPS, INS and TRN (Terrain Referenced Navigation) were integrated. It is concluded that an integrated navigation system can offer a greater robustness and a higher accuracy of the navigation solution, taking into account the weaknesses the individual sensors have. Differential GPS can eliminate a number of systematic errors, improving the attainable accuracy. Author

N93-19928# Kaman Aerospace Corp., Bloomfield, CT.
AN IMPROVED METHOD OF STRUCTURAL DYNAMIC TEST DESIGN FOR GROUND FLYING AND ITS APPLICATION TO THE SH-2F AND SH-2G HELICOPTERS
C. A. TOMASHOFSKI, E. J. NAGY, and P. E. KEARY *In* AGARD, Flight Testing 23 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04
An improved method of structural dynamic test design was developed at Kaman Aerospace Corporation over the past several years. The method, Generalized Force Determination or GFD, grew from experience using basic force determination during the early 1980's. Basic force determination was found to work extremely well for many types of fatigue test setups with limited matching criteria. In other tests, it was found that certain combinations of actuators and matching criteria would render the test rig impossible to calibrate. Basic force determination could not be used for those cases. Since then, the source of the difficulty has been identified, and fundamental theoretic foundations have been built by William G. Flannelly (of Kaman Aerospace Corp.) to generalize the process of force determination for essentially any type of fatigue test arrangement. In addition, GFD has grown into a complete, automated, turn-key software package which guides the test engineer to the best possible solution within the constraints of the available test hardware and provides concrete insight into ways of adapting the hardware arrangement to improve the solution even further. The theoretical foundations are presented in broad outline in this paper. The fatigue tests done on full scale SH-2 helicopters which verified the practical applicability of GFD are described also. The steps in the complete GFD system were honed by the practical knowledge gained during the conduct of these tests. Author

N93-19929# Technische Hogeschool, Delft (Netherlands).
ON-LINE AIRCRAFT STATE AND PARAMETER ESTIMATION
M. LABAN *In* AGARD, Flight Testing 23 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

Detailed mathematical models of aircraft aerodynamics find their use in aircraft design evaluation, flight simulation, control system tuning, and aircraft certification. Unknown parameters in these models can be extracted from flight test data by means of a variety of system identification techniques. This paper shows how on-line aerodynamic model identification has become feasible by applying algorithms based on a decomposition of the state and parameter estimation problem and the application of a high speed multi-processor computer system. Results from a recent flight test program are presented. Author

N93-19930# National Research Council of Canada, Ottawa (Ontario).
THE FLIGHT TEST AND DATA ANALYSIS PROGRAM FOR THE DEVELOPMENT OF A BOEING/DE HAVILLAND DASH 8 SIMULATOR MODEL
STEWART W. BAILLIE, KEN HUI, and JAAP DELEEUW (AERCOL, Downsview, Ontario) *In* AGARD, Flight Testing 19 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

A joint program between CAE Electronics Ltd., Montreal, and the Flight Research Laboratory, NRC, was conducted to develop high fidelity simulator models of the Dash 8 Series 100 and 300 aircraft. This paper focuses primarily on the Series 100 program. The flight test portion of the program entailed a relatively limited set of instrumentation due to aircraft ownership and regulatory constraints. The primary measurements were the basic inertial quantities and flight path reconstruction techniques were used to generate the time histories of other required flight path parameters (such as angle of attack and sideslip). The major portion of flight test data was analyzed using Maximum Likelihood Estimation with reliance on trim condition data for initial model estimates. The final simulator model was validated using specifically designated maneuvers conducted solely for validation purposes. Author

N93-21305# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
THE TESTING OF FIXED WING TANKER AND RECEIVER AIRCRAFT TO ESTABLISH THEIR AIR-TO-AIR REFUELLING CAPABILITIES [LES ESSAIS PRATIQUES SUR LES AVIONS RAVITAILLEURS ET RAVITAILLES AFIN DE DETERMINER LEURS CAPACITES DE RAVITAILLEMENT EN VOL]
JOHN BRADLEY (Aircraft and Armament Evaluation Establishment, Boscombe Down, England.) and KAREN EMERSON (Aircraft and Armament Evaluation Establishment, Boscombe Down, England.) Dec. 1992 27 p *Its* Flight Test Techniques Series
(AGARD-AG-300-VOL-11; ISBN-92-835-0698-7) Copyright Avail: CASI HC A03/MF A01

Since its founding in 1952, the Advisory Group for Aerospace Research and Development has published, through the Flight Mechanics Panel, a number of standard texts in the field of flight testing. The original Flight Test Manual was published in the years of 1954 to 1956. The Manual was divided into four volumes: (1) performance; (2) stability and control; (3) instrumentation catalog; and (4) instrumentation systems. This AGARDograph therefore describes the points that need to be considered when planning AAR trials to clear a new tanker or a new receiver aircraft for Service use. The paper assumes some familiarity with current AAR practices and equipment. It covers the two AAR systems in widespread use, namely the probe and drogue, and boom refuelling systems. Many of the points that need to be considered are common to both. Derived from text

N94-10429# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
NEW HYPERSONIC TEST METHODS DEVELOPED AT ONERA: THE R5 AND F4 WIND TUNNELS [NOUVEAUX MOYENS D'ESSAIS HYPERSONIQUES DEVELOPPES A L'ONERA: LES SOUFFLERIES R5 ET F4]
B. CHANETZ, M.-C. COET, D. NICOUT, T. POT, P. BROUSSAUD, G. FRANCOIS, A. MASSON, and D. VENNEMANN (European Space Agency. Centre Spatial de Toulouse, France.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 12 p (SEE N94-10421 01-02) Apr. 1993 In FRENCH Previously announced in IAA as A92-48600
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

The R5 wind tunnel allows the simulation of hypersonic flows at low Reynolds numbers, corresponding to intake conditions encountered at altitudes of about 60 km. The F4 wind tunnel is projected to study the effects of actual gas and especially effects associated with chemical kinetics during atmospheric reentry. Attention is given to the performance, installation details, and description of the introduction of wind tunnel testing. Author

N94-11318# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Munich (Germany). Military Aircraft Div.
SMART STRUCTURES: A TECHNOLOGY FOR NEXT GENERATION AIRCRAFT
W. SCHMIDT and C. BOLLER *In* AGARD, Smart Structures for Aircraft and Spacecraft 14 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

Performance of aircraft structures has progressed in a sequence of steps during the past. Since composite materials have gained broad application because of significant technological improvement, it is timely to look for the next step in improvement of aircraft performance. It is very likely that this step is related to smart structures technology. Smart structures technology is able to meet various aircraft design objectives such as improved military aircraft effectiveness through improved aircraft capabilities and reduced life cycle cost or reduced direct operating cost of civil aircraft through improvement in performance, fuel consumption, and aircraft maintainability. Active/adaptive structures, structure health monitoring, and structure integrated avionics are the three areas which are felt to be the areas where smart structures technology is most beneficial. Ways for cooperation between various engineering and natural sciences, being a major driving force for the success of smart structures, are described as well as some laboratory scale experiments which were recently performed. It is felt that an increased effort in engineers in various fields towards realization of smart structures can be a new rewarding challenge for the aircraft industry in developing next generation aircraft. Author (revised)

N94-11321# Eurocopter Deutschland G.m.b.H., Munich (Germany).
SMART MATERIALS FOR HELICOPTER ROTOR ACTIVE CONTROL
H. STREHLOW and H. RAPP *In* AGARD, Smart Structures for Aircraft and Spacecraft 16 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

A major improvement of helicopter performance and comfort can be achieved by the implementation of rotor active control technology (RACT). The introduction of individual blade control (IBC) is a subject of current research activities. But the breakthrough of this technology is still missing due to the lack of appropriate rotating blade actuation systems. Smart materials may open a new possibility for the realization of rotor active control. A survey of current hydraulic individual blade actuation systems shows that these are very complicated and heavy. Blade actuation by smart materials offers the change for an electrical system integrated into the blade itself. A study of different blade actuation systems shows that in principle there is the possibility of achieving this goal. But, today the available materials are not ready for real 'smart' applications. The preferred materials - piezoceramics - show a too low tension strength and very low active strains. Therefore, at this time the only feasible blade actuation system for individual blade control seems to be a hinged flap at the outer third of a rotor blade. This flap can be controlled by a smart (piezoelectric) actuator. Estimations show that such a system will work on the desired yaw. Author (revised)

N94-11341*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

THE IMPACT OF ACTIVE CONTROLS TECHNOLOGY ON THE STRUCTURAL INTEGRITY OF AERONAUTICAL VEHICLES

THOMAS E. NOLL, EDWARD AUSTIN (Army Aviation Research and Technology Activity, Hampton, VA.), SHAWN DONLEY (Naval Air Development Center, Warminster, PA.), GEORGE GRAHAM (National Defence Headquarters, Ottawa, Ontario.), TERRY HARRIS (Wright Lab., Wright-Patterson AFB, OH.), IAN KAYNES (Defence Research Agency, Farnborough, England.), BEN LEE (Institute for Aerospace Research, Ottawa, Ontario.), and JAMES SPARROW (Aeronautical Research Labs., Melbourne, Australia.) *In* AGARD, Smart Structures for Aircraft and Spacecraft 10 p (SEE N94-11317 01-24) Apr. 1993

(AGARD-CP-531) Copyright Avail: CASI HC A02/MF A04

The findings of an investigation conducted under the auspices of The Technical Cooperation Program (TTCP) to assess the impact of active controls technology on the structural integrity of aeronautical vehicles and to evaluate the present state-of-the-art for predicting loads caused by a flight-control system modification and the resulting change in the fatigue life of the flight vehicle are summarized. Important points concerning structural technology considerations implicit in applying active controls technology in new aircraft are summarized. These points are well founded and based upon information received from within the aerospace industry and government laboratories, acquired by sponsoring workshops which brought together experts from contributing and interacting technical disciplines, and obtained by conducting a case study to independently assess the state of the technology. The paper concludes that communication between technical disciplines is absolutely essential in the design of future high performance aircraft. Author (revised)

N94-11345# Stirling Dynamics Ltd., Bristol (England).

ACTIVE LANDING GEAR CONTROL FOR IMPROVED RIDE QUALITY DURING GROUND ROLL

TYRONE F. CATT, DAVID COWLING (Bristol Univ., England.), and ALAN SHEPHERD *In* AGARD, Smart Structures for Aircraft and Spacecraft 11 p (SEE N94-11317 01-24) Apr. 1993 Sponsored in part by British Aerospace Public Ltd. Co.

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Active control of an aircraft landing gear can give improved passenger ride quality during take-off and landing. The active control system studied uses feedback from airframe mounted sensors to modify rigid body and structural response. The system is based primarily on modifying the damping characteristics in the nose gear oleo. This is achieved by reducing the damping orifice area, with active control of the area about this new datum value. In addition, the benefits of a fully active nose gear using a separate supply of high pressure hydraulic fluid are evaluated. Significant benefits are demonstrated with the active damping control system compared with the basic landing gear. Responses to general runway roughness and discrete runway bumps are considered. The active damping control system is shown to be effective in reducing peak and rms passenger normal accelerations at all fuselage stations, particularly nose and tail. Good improvement can be obtained from active damping control of the nose gear, with no modification to the main gear. The first fuselage bending mode response can be reduced by active damping control. The benefits from the fully active system are marginal, considering the additional system complication. These effects are illustrated for a typical transport aircraft configuration. Author

N94-11347# Wright Lab., Wright-Patterson AFB, OH.

MULTIDIMENSIONAL INTELLIGENT CONTROL FOR SUPERLIGHT AIR VEHICLES

AIVARS SMITCHENS, ANTHONY DETHOMAS, KURT GREVSTAD (Boeing Co., Seattle, WA.), and DOUG MOORE (Rockwell International Corp., El Segundo, CA.) *In* AGARD, Smart Structures for Aircraft and Spacecraft 12 p (SEE N94-11317 01-24) Apr. 1993

(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

Flexible wing technology was explored in a number of design studies. Wind tunnel experiments generally affirm the results of these studies that a flexible, variable twist wing holds the potential for dramatic air vehicle performance improvements. However, the attendant control reversal, increase in control parameter nonlinearities, and the need for an active control system to suppress flutter has discouraged the application of this technology in production designs. Advancement of a robust control capability for damping structural modes; embedded sensors to provide required inputs to the control system for active flutter control and, possibly, battle damage tolerance; high-speed on-board computation; and other technologies promise the capability to exploit the benefits promised by more flexible structures. Current proposals to reduce air vehicle structural weight are briefly reviewed and implications on the control system are assessed. Even though control system concerns exist, they are resolvable and it may be timely to undertake the development and demonstration of an actively controlled flexible wing. Author (revised)

N94-18240# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

NON-LINEAR FLIGHT DYNAMICS

P. GUICHETEAU *In* AGARD, Non Linear Dynamics and Chaos 13 p (SEE N94-18236 04-77) Jun. 1993 Sponsored in part by Services Techniques des Programmes Aeronatiques

(AGARD-LS-191) Copyright Avail: CASI HC A03/MF A02

In Flight Dynamics, aircraft motion is described by a set of non-linear differential equations, depending on parameters, associating the state vector (angle of attack, sideslip angle, speed, angular rates, etc.) with the control vector (motivators, etc.) through flight dynamics equations, aerodynamic model, and flight control system. Some works which aim at improving the knowledge and the prediction of aircraft behavior, in particular flight phases for which classical linearized analysis of non-linear differential equations is insufficient or not valid, are presented. Author (revised)

N94-18418# Politecnico di Milano, Milan (Italy). Dipt. di Ingegneria Aerospaziale.

A DESIGN PROCEDURE FOR SLOTTED FLAPS

SERGIO DEPONTE, ALESSANDRO CELLA, and MARIO MARCAZZAN *In* AGARD, High-Lift System Aerodynamics 6 p (SEE N94-18415 04-01) Sep. 1993 Sponsored in part by CNR

(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

In the design of slotted flaps it is attempted to avoid a reacceleration between the trailing edge of an upstream element of the system and the peak velocity of the downstream element, to reach the maximum lift. It is proved that it is possible by means of a numerical procedure based on a vortex distribution. The resulting shapes are then discussed with reference to the application to a real design. Author

N94-18431# Defence Research Agency, Farnborough, Hampshire (England).

AN EXPERIMENTAL INVESTIGATION OF THE OPTIMUM SLAT SETTING ON A COMBAT AIRCRAFT MODEL

I. R. M. MOIR *In* AGARD, High-Lift System Aerodynamics 16 p (SEE N94-18415 04-01) Sep. 1993

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Tests have been carried out, on a combat aircraft model with high-lift devices, in the DRA Farnborough 5-meter pressurized low-speed wind tunnel. The deflection angle and position of a leading-edge slat were varied and optimum settings established. The separate effects of Reynolds number and Mach number on overall lift coefficient and on the optimum slat setting were investigated. The results show that optimum performance is achieved at a very high slat deflection angle and the performance is strongly influenced by compressibility effects. Author

N94-18432# Defence Research Agency, Farnborough, Hampshire (England).

AN EXPERIMENTAL INVESTIGATION OF ATTACHMENT-LINE TRANSITION ON THE SLAT OF A COMBAT AIRCRAFT MODEL

B. C. HARDY *In* AGARD, High-Lift System Aerodynamics 11 p (SEE N94-18415 04-01) Sep. 1993

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An experimental investigation into scale effect at low speed and high lift has been carried out in the DRA 5-m, pressurized wind tunnel on a subsonic strike-fighter model equipped with slotted high-lift devices. The attachment-line boundary layer on the leading-edge slat was found to be turbulent on the outboard part of the wing near maximum lift for a range of unit Reynolds number. An adverse Reynolds number effect on maximum lift was measured

which correlated quite well with the onset of attachment-line transition. The conditions for onset of transition were not consistent with the assumption of gross contamination by the fuselage boundary layer, the attachment-line boundary layer remaining laminar on the inboard slat to more than double the expected free-stream Reynolds number. It is suggested that this result is due to spanwise variation in attachment-line position, which results in suppression of the disturbances emanating from the root region of the high-lift wing. It is concluded that attachment-line transition is a potentially significant factor in wind tunnel testing of high-lift wings equipped with leading-edge slats. Author

N94-18436# Wright Lab., Wright-Patterson AFB, OH.
HIGH LIFT AND THE FORWARD SWEPT WING
LAWRENCE A. WALCHLI *In* AGARD, High-Lift System Aerodynamics 9 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

A broad overview of the X-29 Forward Swept Wing (FSW) Technology Demonstrator Program traces the aircraft's history from design through flight test. Brief descriptions of the aircraft and its flight control system provide insight for evaluating this unique vehicle. Wind tunnel design data substantiate theory and highlight potential solutions to a more 'missionized' aircraft. Flight test results validate the X-29's wind tunnel data base and provide for piloted simulation of possible improvements for the specific X-29 technologies. Author

N94-18442# Aerospatiale, Toulouse (France). Div. Avions.
HIGH-LIFT RESEARCH: APPLICATION TO THE DESIGN OF THE ATR72 FLAP
P. CAPBERN *In* AGARD, High-Lift System Aerodynamics 10 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

Due to slightly reduced Clmax objectives in landing configuration for the ATR72, compared to the ATR42, the high-lift system of the ATR72 is made up of a single dropped hinge flap, whereas the ATR42 was equipped with a double slotted vane type flap. Elimination of the vane has had a beneficial effect in greatly simplifying the high-lift system for the ATR72. This simplification has been achieved while ensuring that Clmax levels are maintained or improved at same flap deflection (up to the value required for landing), and take-off L/D ratio is improved, which has a direct repercussion on operational performance, such as minimum runway lengths and maximum take-off weight. This aerodynamic performance has been achieved thanks to the systematic introduction, since 1985, of numerical methods in the design phase, in addition to the empirical and experimental methods used almost exclusively until then. The ATR72 flap is indeed the first to be essentially designed with numerical methods at Aerospatiale. Beside this, more severe new regulations for turboprop A/C, leading to a restriction in the use of large flap deflections for the ATR42, the effect of the elimination of the vane on Clmax has been numerically investigated for this A/C. This study having shown promising results, some wind-tunnel and flight test verifications were conducted which confirmed the reliability of the numerical tools. The development of new design and analysis methods has been pursued; it has involved, on one hand, an extension of their field of use and the quality of the modeling, and, on the other, a reduction in the design cycle time. The objective was twofold: better optimization of high-lift systems, and, above all, an appreciable reduction in the associated design costs. Author

N94-18443# Short Bros. and Harland Ltd., Belfast (United Kingdom). Aerodynamics Dept.
THE AERO-MECHANICAL DESIGN OF A NOVEL FOWLER FLAP MECHANISM
J. R. MATHEWS *In* AGARD, High-Lift System Aerodynamics 9 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A02/MF A04

The flow around a 2-dimensional wing and flap is reviewed using inviscid and viscous computational fluid dynamic techniques. In particular, the effect of flap gap is explored. The results indicate that for optimum aerodynamic performance at low flap angles, flap gaps in the region of 2 to 3 percent are required. A novel 4-bar Fowler flap mechanism is described which is shown to give these required gaps for flap angles greater than 3 degrees. Such a mechanism can be readily optimized for minimum flap overlap at specified take-off flap settings. A comparison of a track and roller arrangement with the 4-bar mechanism indicates significant advantages for the latter. Author

N94-18444# Boeing Defense and Space Group, Seattle, WA.
DESIGN, DEVELOPMENT, AND FLIGHT EVALUATION OF THE BOEING YC-14 USB POWERED LIFT AIRCRAFT
TED C. NARK *In* AGARD, High-Lift System Aerodynamics 17 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

The Boeing YC-14 was designed to perform a 400nm mission carrying a 26000 lb payload and land in 2000 feet on a semi-prepared landing strip. The high-lift system was one that had never been flown before; a upper surface blowing (USB) concept utilizing the 'Coanda' effect. The take-off and landing performance estimates developed from wind tunnel data were completely substantiated in the flight test program. The critical issue of continuing either a landing or takeoff after the loss of one of the two CF6 engines was also proven in the flight test program. The design details behind the performance of the YC-14 are discussed and some of the performance features of the airplane are explained. Author (revised)

N94-18445# Deutsche Airbus G.m.b.H., Bremen (Germany). Aerodynamics Dept.
HIGH-LIFT DESIGN FOR LARGE CIVIL AIRCRAFT
A. FLAIG and R. HILBIG *In* AGARD, High-Lift System Aerodynamics 12 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

A general reflection of the high-lift system design process is given in the first part of the presentation. First the objectives and constraints are reflected which drive the high-lift design for civil transport aircraft. Further information is given on the applied theoretical methods and the Deutsche Airbus wind-tunnel strategy. An example of the high-lift system design process is given in the second part of the presentation. This deals with the conversion of a single-slotted Fowler flap to a part span double slotted flap, a high-lift system which was developed by Deutsche Airbus for the A-321. Author (revised)

N94-18446# De Havilland Aircraft Co. of Canada Ltd., Downsview (Ontario). Technology and Research.
HIGH LIFT SYSTEMS FOR TRANSPORT AIRCRAFT WITH ADVANCED AIRFOILS
B. EGGLESTON and R. J. D. POOLE *In* AGARD, High-Lift System Aerodynamics 13 p (SEE N94-18415 04-01) Sep. 1993
Sponsored in part by National Research Council of Canada
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

This paper describes an on-going program of R&D into the development of high lift systems for future propeller driven regional transport aircraft. The work includes tests of two-dimensional airfoils and flaps, while half models are used for wing integration development. Comparisons are made between earlier commuter airfoil designs and advanced supercritical airfoils capable of NLF (natural laminar flow), using single and double-slotted flap systems in both cases. The advanced airfoils were also tested with a leading edge slat. Some effects of Reynolds number on lift characteristics are reviewed which show airfoils without leading edge slats were more sensitive at the scale of the half model used and that higher Reynolds numbers may be required. The advanced airfoils stalled at lower incidences than the commuter airfoils which are much thicker and better tailored to high lift performance. Advanced airfoils will likely require an additional flap segment to achieve similar lift to commuter airfoils. Leading edge slats gave large increases in maximum lift coefficients (up to 30 percent), which would allow substantial increases in wing loading if needed for the future. The half model development has entailed work on improving the sealing of the fuselage to the tunnel wall to minimize leakage. The paper provides some details of such work on high lift models and also on models used for cruise drag investigations. Author

N94-18447# Alenia Aeronautica, Naples (Italy). Flight Technology.
CHOICE AND OPTIMIZATION OF A HIGH-LIFT SYSTEM FOR AN ADVANCED AMPHIBIOUS AIRCRAFT
M. A. AVERARDO, M. DELEO, and V. RUSSO *In* AGARD, High-Lift System Aerodynamics 13 p (SEE N94-18415 04-01) Sep. 1993
(AGARD-CP-515) Copyright Avail: CASI HC A03/MF A04

The design history of a flap system for an advanced amphibious aircraft is presented in this paper. All the most significant phases of the 2D theoretical studies and the experimental 2D and 3D investigations which have allowed to achieve the final geometry of the high-lift device will be described and, hence, the design criteria, the methods of analysis, the choices will be pointed out. Starting from the preliminary design of several flap systems, the development of this project needed a great deal of numerical studies and wind-tunnel tests in order to select, step by step, the most efficient geometries and to optimize the flap configurations. So, different technical aspects involved with these activities will be discussed: the choice of the flap types to be investigated, related to the special aerodynamic requirements of an amphibious aircraft and to the needs of other design areas (structure, weight, production); the geometrical elements effecting the aerodynamic performance of a high-lift device; general problems connected with theoretical and experimental studies of multi-body systems.
Author (revised)

N94-24313# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
INTEGRATED AIRFRAME DESIGN TECHNOLOGY [LES TECHNOLOGIES POUR LA CONCEPTION INTEGREE DES CELLULES]
Dec. 1993 173 p In ENGLISH and FRENCH Workshop held in Antalya, Turkey, 19-20 Apr. 1993
(AGARD-R-794; AD-A276837; ISBN-92-835-0729-0) Copyright Avail: CASI HC A08/MF A02

Integrated airframe design embraces the concept of bringing together all of the aspects of airframe design, including various disciplines such as structures, materials, aerodynamics, controls, and manufacturing, from conceptual design all the way through manufacturing. It also includes the sub-disciplines which are involved in each discipline and the interactions these have with one another. Moreover, an IAD process also affects the organizational structure of the personnel. In order to provide a broad-based approach to evaluating and identifying future research and development directions required to provide IAD technology, the First Integrated Airframe Design Technology Workshop, sponsored by AGARD, was held in Antalya, Turkey on 19-20 Apr. 1993. This document summarizes the output of that Workshop. For individual titles, see N94-24314 through N94-24327.

N94-24314*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NEW COMPUTING SYSTEMS, FUTURE COMPUTING ENVIRONMENT, AND THEIR IMPLICATIONS ON STRUCTURAL ANALYSIS AND DESIGN
AHMED K. NOOR and JERROLD M. HOUSNER *In* AGARD, Integrated Airframe Design Technology 25 p (SEE N94-24313 06-05) Dec. 1993
(Contract(s)/Grant(s): NCCW-11)
(AGARD-R-794) Copyright Avail: CASI HC A03/MF A02

Recent advances in computer technology that are likely to impact structural analysis and design of flight vehicles are reviewed. A brief summary is given of the advances in microelectronics, networking technologies, and in the user-interface hardware and software. The major features of new and projected computing systems, including high performance computers, parallel processing machines, and small systems, are described. Advances in programming environments, numerical algorithms, and computational strategies for new computing systems are reviewed. The impact of the advances in computer technology on structural analysis and the design of flight vehicles is described. A scenario for future computing paradigms is presented, and the near-term needs in the computational structures area are outlined.
Author (revised)

N94-24315# Wright Lab., Wright-Patterson AFB, OH. Manufacturing Technology Directorate.
EARLY MANUFACTURING CONSIDERATIONS IN DESIGN
WILLIAM C. KESSLER, GERALD C. SHUMAKER, and MICHAEL F. HITCHCOCK *In* AGARD, Integrated Airframe Design Technology 7 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A02/MF A02

The successful and timely transition of new product technologies to weapon systems depends heavily on the technical maturity, flexibility, and cost effectiveness of the critical manufacturing processes and systems required to turn these technologies into tangible products. The whole concept of Integrated Product Process Development (a.k.a. Concurrent Engineering) encourages and facilitates the parallel design and development of these manufacturing processes and systems with the design and development of the product. As a result of new computer aided technologies and increased emphasis on manufacturing design, new tools and methodologies are emerging that will facilitate the early consideration of manufacturing in design. This paper will address the development of two such tools: Producibility Methodology; and Tools and Virtual Manufacturing. These tools will enhance the effectiveness of manufacturing engineers who are integrated product process development team members and enable design engineers to better understand the potential downstream implications of early design decisions.
Author (revised)

N94-24316# Deutsche Aerospace A.G., Munich (Germany).
APPLICATIONS OF CFD CODES AND SUPERCOMPUTERS TO AIRCRAFT DESIGN ACTIVITIES
W. SCHMIDT and P. W. SACHER *In* AGARD, Integrated Airframe Design Technology 9 p (SEE N94-24313 06-05) Dec. 1993
Sponsored in part by Aerospatiale; DLR; Aachen Univ.; Stuttgart Univ.; Dornier System G.m.b.H.; and Deutsche Airbus G.m.b.H.
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Integrated Design Technology has been pushed to a large extent by the tremendous progress achieved in the last two decades in the field of computational techniques with regard to flow simulation, engineering, and manufacturing. This paper concentrates on the impact of CFD on the overall design process reviewed from the view of aircraft industry in Germany. Selected examples will be given for applications of CFD during design and development of major products of European aerospace industry without claiming for completeness. General product categories and technology areas involved will be identified as having large potential for CFD and supercomputing efforts. In addition, present technology thrusts will be discussed, and examples for the impact of CFD and supercomputing demonstrated by applications in various programs will be given.
Author (revised)

N94-24317*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PROBABILISTIC SIMULATION OF CONCURRENT ENGINEERING OF PROPULSION SYSTEMS
C. C. CHAMIS and S. N. SINGHAL (Sverdrup Technology, Inc., Brook Park, OH.) *In* AGARD, Integrated Airframe Design Technology 10 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A02/MF A02

Technology readiness and the available infrastructure is assessed for timely computational simulation of concurrent engineering for propulsion systems. Results for initial coupled multidisciplinary, fabrication-process, and system simulators are presented including uncertainties inherent in various facets of engineering processes. An approach is outlined for computationally formalizing the concurrent engineering process from cradle-to-grave via discipline dedicated workstations linked with a common database.
Author (revised)

N94-24318# British Aerospace Defence Ltd., Preston (England). Military Aircraft Div.
FRAMEWORKS FOR INTEGRATED AIRFRAME DESIGN
A. L. SHAW *In* AGARD, Integrated Airframe Design Technology 15 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A03/MF A02

British Aerospace is Britain's largest Manufacturing Group. Its products are divided into the following groups: Defense Systems, Commercial Aircraft, Cars, Civil Engineering, Property Development, Construction, and Project Management. BAe Defense is the largest

defense company in Europe with a turnover of 4.2 billion British pounds. Its exports account for over 70 percent of the total sales. The Military Aircraft Division is an important part of the BAe Defense group. Its major projects are centered around the HAWK, HARRIER, TORNADO, and the European Fighter Aircraft EFA projects.
Author (revised)

N94-24319# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft Div.
THE PROCESS NETWORK IN THE DESIGN AND MANUFACTURING OF AIRCRAFT
J. KRAMMER and A. RUETTINGER *In* AGARD, Integrated Airframe Design Technology 10 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A02/MF A02
The first part of this paper presents some ideas for the investigation and improvement of developmental processes. Typical processes are shown using the Structured Analysis and Design Technique (SADT) and a process flow diagram. In the second part, a redesigned process chain for the design and manufacturing of complex composite parts is explained. Two examples show the functionality of the newly developed constructive design model for this process. Author (revised)

N94-24320# Deutsche Airbus G.m.b.H., Hamburg (Germany). Structural Mechanics Dept.
INTEGRATED STRESS AND STRENGTH ANALYSIS OF AIRPLANE STRUCTURES USING THE DATA PROCESSING TOOL ISSY
R. WERNER, M. WIEDEMANN, and B. EVERS *In* AGARD, Integrated Airframe Design Technology 3 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A01/MF A02
The Integrated Structural Mechanics System (ISSY) is a modular structured tool used to perform a variety of different structural calculations on aircraft structures. ISSY integrates all model generation, analysis and evaluation programs used in structural mechanics under one user interface, and operates a common data base for all these programs. ISSY can be used to generate and analyze calculation models of structural assemblies (fuselage, wings, stabilizers, etc). This is performed by an interactive preprocessor implemented in ISSY. These calculations provide data for both the finite element analysis and for strength analysis, thereby avoiding redundancy of data. Model generation is supported by the use of parameterized standard models (and/or standard sub-models). In addition, model generation is made easier by comprehensive ISSY libraries which provide material data on aluminum, composites, in addition to geometric data on profile sections and rivet allowables. The geometry input data can be directly copied from the component loft data files. The model input data and calculation results are stored in relational data tables which can be analyzed by the postprocessor implemented in ISSY. In addition other modules convert conventionally generated calculation models into ISSY format and generate load case data. To aid partners work on international joint projects, ISSY is compatible with both standard NASTRAN and ISSY processed input and output data. A documentation of model and result data can be obtained in every phase of the justification report. Author

N94-24321# McDonnell-Douglas Corp., Saint Louis, MO.
APPLICATION OF CONCURRENT ENGINEERING PRINCIPLES TO AIRCRAFT STRUCTURAL DESIGN
M. DROEGKAMP, T. W. HESTERMAN, B. L. MATTHEWS, T. M. WILSON, and JOHN M. COYLE *In* AGARD, Integrated Airframe Design Technology 9 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A02/MF A02
The process of designing aircraft structure requires many functional disciplines and associated interdisciplinary coupling. To achieve optimal performance, the various disciplines must work closely together and effectively exchange large amounts of pertinent data. In the past, this was accomplished either with independent analysis tools that were not tightly coupled or with a single analysis tool that lacked the required fidelity to truly support the needs of more than one discipline. In addition, the analyses were performed in series rather than concurrently. A major impediment to process improvement was the lack of a common geometry database that could be utilized by all disciplines required to support structural design. The rapid growth of computational capability and the gradual acceptance by engineers and management to the use of automated processes and common databases has allowed McDonnell Douglas Aerospace (MDA) to implement a concurrent engineering approach to structural design. Our present aircraft design process combines a common geometry approach and existing analysis tools with the power of engineering workstations to manipulate an integrated design database to arrive at an optimum design solution. Our modular approach divides the design process into smaller, more manageable tasks that can be performed concurrently. It achieves 'buy-in' from each engineering and manufacturing discipline by incorporating existing specialized design tools that have been developed by those groups and introduced into the process without taking away ownership. We use common geometry principles, neutral file structures, widely accepted third party and company proprietary applications coupled with consistent naming conventions and file management to achieve our integrated design methodology solution. The present system optimizes the vehicle structure for minimum weight against a given set of design requirements. It is currently used to evaluate advanced vehicles such as NASP and is also being applied to more conventional aircraft. In the future, capabilities will be added to this analysis system that allow it to be applied to detail design problems as well as increasing the fidelity of advanced design solutions. The major increase in capability will result from adding direct access to the computer aided design geometry and also in the incorporation of standard analysis checks into the system. We will design the architecture of the system such that new engineering and manufacturing applications can be easily added. This paper will discuss the evolution of the MDA integrated design methodology from the 80's to the present as well as our vision of the future. Author

N94-24322# Fokker B.V., Schipol-Oost (Netherlands).
SOME PRACTICAL PROBLEMS IN MULTIDISCIPLINARY DESIGN AND OPTIMISATION
D. J. LAAN, H. WALGEMOED, C. SCHIMMEL, and R. HOUWINK *In* AGARD, Integrated Airframe Design Technology 7 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A02/MF A02
Structural optimization software bears a great promise in multidisciplinary design as an effective way to find an optimal balance between the requirements from different disciplines. Due to the evolution of the airworthiness requirements and the increased complexity of aircraft systems it has become increasingly more difficult in the last few decades to establish the design loads. Thus, a clear need exists for quick and reliable load estimation procedures. The paper discusses some measures that can be taken to improve the load definition process. Finally, some examples of successful application of structural optimization software at Fokker Aircraft are given. The primary advantage of structural optimization software is that it aids a skilled designer in gaining a feel for the design space. It should aid the designer in his creative task instead of distracting his attention to using the software. This requires the software to be user friendly and to have built-in features for global and local sensitivity studies.
Derived from text

N94-24323# Deutsche Airbus G.m.b.H., Hamburg (Germany).
INFLUENCE OF ACTIVE CONTROLS ON THE DESIGN PROCESS OF A LARGE TRANSPORT AIRCRAFT
M. MOLZOW and H. ZIMMERMANN (Deutsche Airbus G.m.b.H., Bremen, Germany.) *In* AGARD, Integrated Airframe Design Technology 12 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A03/MF A02
The high complexity of an active controlled civil transport aircraft design with its multiple interactions between the different disciplines was presented. It was highlighted that in future design of this kind, different design procedures have to be established with the target to reduce the dominance of one discipline by a multidisciplinary optimization process to ensure an overall aircraft optimum. This has the consequence that the data availability in a certain quality (stiffnesses, aero data, systems data) must be better synchronized with the needs of the user of these data (handling quality, system, loads, flutter, structures) and that cost functions are introduced in the beginning of the design work to ensure a balanced design. It is the firm belief of the authors that already this would be an important step forward. Active Control systems are rather easily capable of being integrated by having in mind to

use signals from additional sensors distributed over the A/C than are available from the ADIRU. There are some doubts that all these relations and interactions in real aircraft design can be replaced one day by a totally automated process but certainly more parts have to be put into a process chain to improve quality and safe design time. Author (revised)

N94-24324# McDonnell-Douglas Aerospace, Long Beach, CA.
CURRENT AND FUTURE DESIGN METHODS FOR LARGE TRANSPORT AIRCRAFT
J. P. GIESING, G. T. J. TZONG, and B. E. SCHOFIELD *In* AGARD, Integrated Airframe Design Technology 15 p (SEE N94-24313 06-05) Dec. 1993 Prepared in cooperation with Douglas Aircraft Co., Inc., Long Beach, CA
(AGARD-R-794) Copyright Avail: CASI HC A03/MF A02

Current aircraft industry design practices produce high quality, safe, and affordable aircraft. However, future advanced and integrated methods offer the opportunity to significantly reduce the cost and development time of aircraft designs. This paper presents an overview of the current design process and an example for subsonic transport wing box design. It also describes a future process which is presently being implemented at the Douglas Aircraft Company, i.e. the Aeroelastic Design Optimization Program (ADOP), and its application to a similar subsonic transport wing. Specifically, stress and flutter are optimized and compression surface buckling and tension surface damage tolerance are integrated. Finally, the future direction of ADOP will be outlined which includes integration of aeroelastic loads, durability and damage tolerance, and concurrent structure and active controls optimization. Author

N94-24325# Alenia Aeronautica, Turin (Italy). Div. Velivoli Difesa.
THE INTEGRATION OF DESIGN AND MANUFACTURING PROCESSES AT ALENIA DVD
L. CHESTA, M. FLACCAVENTO, G. POLLANO, and F. STAROPOLI *In* AGARD, Integrated Airframe Design Technology 16 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A03/MF A02

In aeronautics, the age of high creativity, like the one in the fifties with the introduction of jet engines or the one in the thirties which started the age of monoplanes with metallic shell structures, is passed. Today, we are in a situation in which the final increment in basic performance (maximum speed, maneuver capability) is usually excessively expensive. It is now necessary to look to marginal areas to gain improvements in performance, to use new materials such as carbon fibers to tailor the structure to specific needs, and to simplify, with the help of electronics and servomechanisms, complicated mechanical systems to obtain aircraft architectures otherwise impossible to fly. But this is not enough; it is absolutely necessary to also improve the cost effectiveness by increasing the reliability, availability, and supportability of the weapon system, thereby reducing the usage cost and the production cost of the aircraft. This is not any more achievable using the single man capabilities on a single discipline, but it requires a new type of working organization which uses sophisticated means of calculation, integrated in order to optimize the overall design, and which compresses the time of the process by exploiting the synergism of the interdisciplinary couplings, overlapping as much as possible the design and manufacturing phases. Alenia Defense Aircraft Division, being involved in several programs, both by itself and in international cooperation, has followed this evolution and is actively pursuing the adequacy of its operative structure to the new requirements by adopting advanced technology processes. Derived from text

N94-24327# Dassault (E. M.) Co., Saint-Cloud (France).
TRENDS OF DESIGN METHODOLOGY OF AIRFRAME [TENDANCES DANS LA METHODE DE CONCEPTION DES CELLULES D'AVION MILITAIRE]
C. PETIAU *In* AGARD, Integrated Airframe Design Technology 6 p (SEE N94-24313 06-05) Dec. 1993 In FRENCH
(AGARD-R-794) Copyright Avail: CASI HC A02/MF A02

First, it is reminded that organization of airframe design is directly linked to the performances of available tools. As a matter of fact, they condition the number and nature of project iterations. The organization which should nowadays be recommended in view of the means of CAD, computation and mathematical optimization at our disposal is presented and analyzed. This leads to a first design, followed by experimental verifications with a key role for flight tests. The final design is checked with the help of calculations models calibrated on tests. Then the new tools which are the factors of future evolution of design methodology are examined: to dispose of 'Design History' corresponding to the whole data of the process; parametric CAD and shape optimization; multidisciplinary optimization; 'Feature' Design; improvement of computation methods. As a conclusion we insist on the fact that aircraft manufacturers, CAD suppliers, and scientific searchers will be well advised to create a dialogue as to future design methodology. Author (revised)

N94-28017# British Aerospace Defence Ltd., Farnborough (England).
EXPERIMENTS INTO THE SCALING PARAMETERS REQUIRED FOR EXHAUST GAS INGESTION TESTING OF VERTICAL LANDING AIRCRAFT
P. CURTIS and P. J. BRADLEY *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 9 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

The phenomenon of Hot Gas Recirculation for vertical landing jet aircraft and the effect of exhaust gas ingestion on aircraft performance is described. Additionally, our experience with experimental modelling of HGR for aircraft configurations and the scaling of the important parameters is presented. The conflict between scaling the buoyancy of the flowfield and correct modelling of the pressure field is explored, and a number of fundamental experiments addressing this problem are related. It is shown that in the region close to the jets and when the aircraft is very close to the ground that there are quite large differences between the two scaling criteria; the near-field region requires full scale pressures for accurate representation. Away from this region, the Nozzle Pressure Ratio does not greatly affect the flowfield. Testing of a generic aircraft model with a number of different configurations shows that once near-field flowpaths have been eliminated the ingestion levels are underpredicted if the flow-field buoyancy is below full scale. Absolute levels of ingestion are not greatly different between the two scaling criteria, particularly with the large scatter in results which is endemic to the phenomenon. However, it is concluded that for practical configurations, i.e., those with low levels of ingestion, scaling of flowfield buoyancy is more correct than scaling of the pressure field. This method of scaling is appropriate for use in achieving a low ingestion configuration. Author (revised)

N94-28033*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NUMERICAL SIMULATION OF A POWERED-LIFT LANDING
KALPANA CHAWLA (MCAT Inst., Moffett Field, CA.) and WILLIAM R. VANDALSEM *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

The flow field about a delta wing equipped with thrust reverse jets in slow speed flight near the ground has been computed. Results include the prediction of the flow about the delta wing at four fixed heights above the ground, and simulated landing, in which the delta wing descends towards the ground. Comparison of computed and experimental lift coefficients indicates that the simulations can capture at least the qualitative trends in lift-loss encountered by thrust-vectoring aircraft operating in ground effect. Author

N94-28034# Wright Lab., Wright-Patterson AFB, OH.
A STUDY OF JET EFFECT AND GROUND EFFECT INTERFERENCE ON A STOL FIGHTER
DAVID J. MOORHOUSE, JAMES G. REINSBERG (McDonnell-Douglas Aerospace Information Services Co., Saint Louis, MO.), and FRANK J. SHIRK (McDonnell-Douglas Aerospace Information Services Co., Saint Louis, MO.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

The STOL and Maneuver Technology Demonstrator (S/MTD) program was structured to investigate, develop and validate through analysis, experiment and flight test, four specific technologies

related to providing current and future high performance fighters with both STOL capability and enhanced combat mission performance. The four technologies are: (1) Two-dimensional thrust vectoring and reversing exhaust nozzle, (2) Integrated Flight/Propulsion Control (IFPC) System, (3) Advanced Pilot Vehicle Interface, and (4) Rough/soft field landing gear. In addition to the required technologies, all-moving canard surfaces were also incorporated into the baseline F-15B. As stated previously, the intent of the demonstration program was to validate specific technologies, it was neither a prototype nor an explicit research program. Starting with an existing aircraft, many wind tunnel tests were performed to define the incremental effects of the specific technology items. Thrust reversing was achieved by blocking the nozzle exit area and exhausting the flow through vane packs on top and bottom of the engine. In the Short Landing (SLAND) mode the engines were at full military RPM and all exhaust flow was diverted through final approach with the reverse vanes pointed aft to provide forward thrust. At touchdown, the vanes quickly swing forward to orient the exhaust flow to provide reverse thrust for the rollout. A significant amount of wind tunnel testing was devoted to measuring jet effects at all conditions but definition of jet effects in ground effect received particular emphasis. Reference 1 documented the development of the S/MTD configuration with details on the wind tunnel data and control laws. Data was presented on the jet effects in ground effect that were predicted. Special control logic was defined to mitigate strong nose-up pitching moments as thrust reversing was initiated after touchdown. A special ground-handling mode was also incorporated for the rollout phase. The flight testing produced some surprising results. The object of the present paper is to document that experience. Data will be summarized briefly for completeness. Pertinent flight test experience will be presented, with results of an innovative analysis technique developed by the contractor. Lastly, future requirements will be discussed. Author

N94-28035*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

TRANSITIONAL FLIGHT CHARACTERISTICS OF A GEOMETRICALLY SIMPLIFIED STOVL MODEL

KARLIN R. ROTH *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) Nov. 1993

(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

The transitional flight characteristics of a geometrically simplified Short Take-Off Vertical Landing (STOVL) aircraft configuration were measured in the NASA Ames 7- by 10-Foot Wind Tunnel. The experiment was designed to provide detailed data for evaluating the capability of computational fluid dynamics methods to predict the important powered lift flow parameters. The model consists of a 60 deg cropped delta wing planform; a blended fuselage; and tandem, circular, high pressure air jets that exit perpendicular to the flat lower surface. Freestream Mach number is limited to a maximum 0.2. Model angle of attack ranges from -10 deg to +20 deg. The nozzle pressure ratios of both jets are varied between 1 and 3, and the jet exit temperatures are maintained at near ambient conditions. Detailed surface pressure measurements show that suction pressure peaks located on the upper surface of the wing during conventional wingborne flight for angles of attack greater than 5 deg move to the wing lower surface at angles of attack less than 0 deg. A reduction in these suction pressure peaks is observed when the lift jets are operating. With sonic jet exit conditions, a freestream Mach number of 0.14, and 0 deg angle of attack, the jet-induced suckdown is equivalent to a 3.7 deg reduction in angle of attack. Schlieren, laser light sheet flow visualization and total pressure measurements in the jet plumes provide a description of the three-dimensional jet efflux flowfield. Author

N94-33875# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

OPERATIONAL AGILITY [LA MANIABILITE OPERATIONNELLE]

Apr. 1994 222 p

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From previous AGARD activities, it was recognized that flying qualities and traditional aircraft performance parameters did not characterize the capability or effectiveness of combat aircraft, although they do offer a guide. Other expert groups had reached a similar conclusion. The subject that arose from these realizations was 'agility'. Recognizing that this was an incomplete or immature concept and that a wide variety of sometimes disparate views existed, the Flight Mechanics Panel formed a further Working Group, WG 19, consisting of specialists from AGARD member countries, to study the subject under the title of 'Operational Agility'. Working sessions were held at places of special interest to the group, between 1991 and 1993. The specific aims of the Working Group were to provide definitions, which are universally acceptable, of the terminologies involved in agility; to collate the results of lessons learned from experiments on agility; to define metrics or figures of merit for use in design and evaluation; to explore and document the theoretical foundations; to explore the operational pay-off of balanced capabilities between the airframe, systems and weapons; to highlight any specialized aspects applicable to rotorcraft; to indicate possible means of evaluation in flight; and to recommend areas for further research and development activities, including possible collaborative projects. The Group has completed its study of operational agility with this report. In undertaking the study, a greater understanding has been reached of those subjects which influence operational agility and how these subjects, via the use of operational agility concepts, may be related to the combat effectiveness of the weapon systems. In reaching this understanding, the Group has proposed definitions of the agility terminology which should prove universally acceptable; it has arrived at the methodology for assessment of the various component systems which contribute to the operational agility or combat effectiveness of a Weapon System; and has listed a number of major conclusions and recommendations. Author

N94-34433# Rolls-Royce Ltd., Bristol (England).

HELICOPTER ENGINE/AIRFRAME INTEGRATION: THE WAY AHEAD

D. L. MANN and D. V. HUMPHERSON *In* AGARD, Technology Requirements for Small Gas Turbines 12 p (SEE N94-34431 10-07) Mar. 1994 Sponsored in part by Ministry of Defence

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The importance of successful integration of a turboshaft engine into the recipient helicopter becomes ever more apparent as the market demands a product which is able to carry more payload, over greater distances, in a reduced time, with greater reliability, and at lower cost. New technology developments in individual vehicle systems alone will not be sufficient to ensure future competitiveness. Engine/airframe integration has a significant, previously neglected, role to play. Important direct performance improvements may potentially be exceeded by synergistic, spin-off benefits to other components. In some areas, such as stealth, adequate consideration of integration matters is becoming mandatory. The paper reviews some helicopter component technology directions and observes the implications of harnessing these technologies into integrated systems. Particular attention is paid to integrated intake and exhaust system designs as well as a more general look at overall vehicle integration. A final section discusses integration technology requirements and how they may be employed to produce a fully integrated airframe and engine design philosophy. Author

N94-34591# Aeronautical Research Inst. of Sweden, Bromma.

FATIGUE MANAGEMENT AND VERIFICATION OF AIRFRAMES

A. F. BLOM and HANS ANSELL *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 25 p (SEE N94-34581 10-39) Mar. 1994

(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

The methodology currently used in Sweden for fatigue management and verification of airframes is described. Applications from the new fighter aircraft JAS39 Gripen are included in order to illustrate the various concepts being considered. Additional experience from recent work on the older fighter 37Viggen is also included to highlight certain differences in the detail analyses, stemming from rather different nominal stress levels in the two aircraft. The present paper discusses the handling of load sequences and load spectra development, stress analyses and fracture mechanics analyses, fatigue crack growth modelling, component and full scale testing, service load monitoring regarding both the dedicated test aircraft, which is used to verify basic load

assumptions, and also the individual load tracking program developed for the new fighter. Author

N94-34592# Lockheed Aeronautical Systems Co., Marietta, GA.
RISK ANALYSIS OF THE C-141 WS405 INNER-TO-OUTER WING JOINT
R. E. ALFORD, R. P. BELL, J. B. COCHRAN, and D. O. HAMMOND *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 10 p (SEE N94-34581 10-39) Mar. 1994 Presented at the Structural Integrity Program Conference, San Antonio, TX, 2-5 Dec. 1991; sponsored by USAF
(AGARD-R-797) Copyright Avail: CASI HC A02/MF A03

It is evident that weapon system management benefits greatly from the use of probabilistic risk assessment methods. The C-141 WS 405 inner-to-outer wing joint provides an actual case of how this technology was implemented by Lockheed and USAF engineers to determine conditions of inspection and repair for the C-141 fleet. Author

N94-34593# Dassault-Breguet Aviation, Saint-Cloud (France).
ASSESSMENT OF IN-SERVICE AIRCRAFT FATIGUE MONITORING PROCESS
R. J. CAZES *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 8 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A02/MF A03

Maintaining the structural integrity of aircraft depends on the initial definition of an inspection program to detect structural damage that may occur in service. Prediction of possible fatigue damage due to the applied loads and conditions of use encountered in service is based on an analysis of the probability of incipient cracks and on an evaluation of the development of undetectable faults assumed to exist between two inspections. The validity of evaluation models is generally demonstrated based on comparisons with results obtained on elementary test pieces subjected to predicted local load conditions in service and used to identify the influence of events such as rare overloads or frequent repetitive small loads. This paper presents the principles for processing in flight signals collected in order to predict structural damage by making in flight integrated calculations, considering influences such as: load signals precision (frequency of points taken); elimination of low amplitude variations; and cycle counting methods for the damage calculation. Author (revised)

N94-34594# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft Div.
THE ROLE OF FATIGUE ANALYSIS FOR DESIGN OF MILITARY AIRCRAFT
R. BOCHMANN and D. WEISGERBER *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 7 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A02/MF A03

A brief overview of the fatigue design method employed at DASA (Deutsche Aerospace AG) for combat aircraft is presented. The efficiency of the fatigue analysis--as embedded in the overall design process--is discussed and compared with full scale testing. Furthermore, possible improvements in the method are suggested. Author (revised)

N94-34595# Wright Lab., Wright-Patterson AFB, OH.
DAMAGE TOLERANCE MANAGEMENT OF THE X-29 VERTICAL TAIL
J. HARTER *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 8 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A02/MF A03

During high angle-of-attack (aoa), less than 25 deg, the X-29 experienced severe vertical tail buffet. Fin tip accelerometer data exceeded 110 g's at approximately 16 Hz. The U.S. Air Force Flight Dynamics Directorate was asked to provide technical support to ensure that the entire X-29 flight test program could be safely conducted. The Flight Dynamics Directorate transitioned an in-house developed crack growth life prediction program to the X-29 program office and NASA/Dryden as well as extensive technical support. Three dimensional crack growth analyses were conducted between flight days to track possible damage growth based on actual strain data collected at critical areas of the vertical tail. The entire high aoa flight test program was completed as planned using MODGRO to predict damage accumulation. The data was used to manage flight maneuvers to maximize useful flight data and minimize structural risk. A follow-on flight test program was conducted with the X-29 to assess Vortex Flow Control. Repair to the tail was required to complete this mission. Analysis and verification testing of the repair was performed by the Flight Dynamics Directorate. At the end of that flight test program, less than 10 percent of the repair life was used. Author (revised)

N94-34596# British Aerospace Defence Ltd., Farnborough (England). Military Aircraft Div.
HARRIER 2: A COMPARISON OF US AND UK APPROACHES TO FATIGUE CLEARANCE
F. S. PERRY *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 27 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A01

The different approaches adopted for the fatigue clearance of the Harrier 2 in United States Marine Corps and Royal Air Force usage are discussed. Brief accounts are given of the impact differing analysis methodologies and national airworthiness requirements have had on fatigue design, test, and monitoring of the airframe. Author (revised)

N94-34597# British Aerospace Defence Ltd., Brough (England). Structures Unit.
FATIGUE DESIGN, TEST AND IN-SERVICE EXPERIENCE OF THE BAE HAWK
JOHN OHARA *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 10 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A02/MF A03

The BAe Hawk family is designed primarily to UK regulations, including the safe life S-N fatigue philosophy. S-N data pertinent to key structural features was assembled at the design stage, and fatigue coupon/element tests were conducted in confirmation. The Hawk TMk.1 full scale fatigue test (FSFT) has continued to lead the RAF fleet, and the test loading has been validated by a major operational loads measurement (OLM) exercise. Incidents arising on the FSFT or in-service are handled by several approaches including S-N and fracture mechanics calculations, testing, statistical analysis, and modifications and/or routine inspections are introduced when necessary. The development of the fatigue life clearances of the BAe Hawk family is discussed with particular emphasis on the confirmatory testing and in-service loads measurement necessary to ensure and maintain fleet aircraft fatigue life clearance. Author

N94-34598# National Aerospace Lab., Amsterdam (Netherlands).
REDUCTION OF FATIGUE LOAD EXPERIENCE AS PART OF THE FATIGUE MANAGEMENT PROGRAM FOR F-16 AIRCRAFT OF THE RNLAF
D. J. SPIEKHOUT *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 11 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

Load monitoring of the F-16 fleet of the RNLAF is carried out by NLR using an electronic device capable of analyzing the signal of a strain gage bridge on one of the main carry through bulkheads. This is done on a sample of the fleet. By making use of the information stored in a large centralized data base system, 'individual airplane tracking' is done. Six times per year, the fatigue damage experience of the fleet is reported to the air staff, expressed in the so called 'crack severity index.' From the measurements it is known that the RNLAF is operating its F-16 fleet in a very damaging way. For this reason, it was decided to investigate the possibilities of how to decrease the severity of flying. In this program much attention has been given to the 'stress per G' relation during a flight. In particular the influence of flying with favorite take off store configurations has been studied. Author (revised)

N94-34599# Lockheed Corp., Fort Worth, TX.
AN OVERVIEW OF THE F-16 SERVICE LIFE APPROACH
J. W. MORROW and G. T. HERRICK *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 9 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A02/MF A03
The F-16 airframe was designed according to the latest USAF philosophy adopted in the 1970s. It has a modular structural arrangement and maximum use has been made of aluminum. It was designed with fracture requirements in mind from its inception. Presented in view-graph format are F-16 requirements for airframe structural durability and safety, F-16 design approach, metals crack growth analysis methodology, fatigue/fracture bulkhead web analysis, test policy comparisons, fatigue and fracture control plan, F-16 force management approach, F-16 fleet management recording systems, and lessons learned. CASI

N94-34605# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
TECHNOLOGIES FOR HIGHLY MANOEUVRABLE AIRCRAFT [LES TECHNOLOGIES POUR LES AERONEFS A HAUTE MANOEUVRABILITE]
Mar. 1994 339 p In ENGLISH and FRENCH Symposium held in Annapolis, MD, 18-21 Oct. 1993
(AD-280271; AGARD-CP-548; ISBN-92-835-0740-1) Copyright Avail: CASI HC A15/MF A03
The new generation of combat aircraft incorporate significant advances in maneuver capability, especially in such areas as post-stall control and sustained supersonic maneuver. These technologies expand the operational capabilities, and are essential for survival in a sophisticated threat scenario, and also to obtain favorable exchange ratios against an opponent using the current generation of fighters. The aim of this symposium was to review the various technologies, which combine to give this increased operational capability, and the techniques which are available or being developed, to overcome the design problems associated with the attainment of these goals. The symposium was divided into six sessions covering propulsion and integrated flight control, aerodynamics and control at high angles of attack, post-stall flight and control, flying qualities applied criteria, agility and simulation. For individual titles, see N94-34606 through N94-34631.

N94-34606# Calspan Corp., Arnold AFS, TN.
USAF/AEDC AERODYNAMIC AND PROPULSION GROUND TEST AND EVALUATION TECHNIQUES FOR HIGHLY MANEUVERABLE AIRCRAFT: CAPABILITIES AND CHALLENGES
EDWARD M. KRAFT, GLEN R. LAZALIER, and M. L. LASTER *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 15 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03
The simulation of highly agile aircraft during the development phase presents a significant challenge to aerodynamic and propulsion ground test and evaluation methodologies. The primary simulation challenges are caused by the inherent unsteady, separated nature of the flow phenomena associated with maneuvering aircraft that cause dynamic effects on the airframe and engine. In general, ground test techniques are quasi-steady and transient effects are represented by linearized superposition of steady-state data and unsteady small disturbances. Current trends in the design of tactical fighter aircraft require close coupling between the airframe, avionics, and propulsion systems. In addition, the extreme attitudes and high angular rate motions of this new breed of vehicle causes a strong nonlinear coupling between components. In the current paper, several aerodynamic and propulsion ground test and evaluation methodologies applicable to maneuvering aircraft are summarized, challenges associated with current techniques are identified, and an emerging integrated test and evaluation concept that can significantly impact the quality, time, and cost of developing a new flight vehicle is introduced. Author

N94-34609# British Aerospace Defence Ltd., Warton (England). Aerodynamics Dept.
DESIGN OF INTEGRATED FLIGHT AND POWERPLANT CONTROL SYSTEMS
C. FIELDING *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 12 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03
This paper describes the work being undertaken by British Aerospace on both of these projects, as a continuation of the flight control and technology demonstration research successfully completed on earlier projects such as the Jaguar Fly-By-Wire and the Experimental Aircraft Programme (EAP). Derived from text

N94-34610# Lockheed Advanced Development Co., Palmdale, CA. Flight Test Branch.
THRUST VECTOR AIDED MANEUVERING OF THE YF-22 ADVANCED TACTICAL FIGHTER PROTOTYPE
ROBERT W. BARHAM *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 14 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03
In the mid 1980s design work began on the U.S. Air Force's next generation air superiority fighter. The F-22 team, consisting of Lockheed, Boeing, and General Dynamics, embraced a design philosophy in which low observable technology, maneuverability, and supersonic performance were given equal consideration. Even with low observable features and long range weapon employment capabilities, the team believed that the probabilities of brief, short range air combat engagements, based on historical precedents and postulated future scenarios, demanded a highly agile design. Thrust vectoring emerged as a key feature for obtaining the desired agility without adversely impacting the aircraft's low observable signature. Thrust vectoring technology was incorporated and flown in the YF-22 Advanced Tactical Fighter prototype to investigate and validate the concept for the production F-22. The airframe, flight control system, and propulsion system were fully integrated. Thrust vectoring commands were generated by the aircraft's flight control computers and sent to each engine controller. Each engine controller independently performed the computations and issued the commands necessary to position the nozzle actuators to the correct vector angle while maintaining commanded thrust levels and engine stall margin. Flight tests showed that thrust vectoring provided major improvements in low speed maneuverability, enhanced handling qualities during tracking, and increased supersonic sustained turn performance as compared to current front line fighters. Author

N94-34611# Wright Lab., Wright-Patterson AFB, OH.
RESULTS FROM THE STOL AND MANEUVER TECHNOLOGY DEMONSTRATION PROGRAM
DAVID J. MOORHOUSE *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 8 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03
The S/MTD program has generated flight test data to validate four specific technologies: 2-D thrust vectoring & reversing nozzle; integrated flight/propulsion control; advanced pilot/vehicle interface including autonomous landing guidance; and rough field/high sink rate landing gear. These technologies have been integrated into an F-15B to provide mission benefits across the complete flight envelope from on-board guidance to a bad weather short landing, through significantly enhanced maneuvering benefits to supersonic performance. These technologies are either transitioning on to other aircraft, or can be considered viable design options for future aircraft. Derived from text

N94-34614# Institut de Mecanique des Fluides de Marseille (France).
TECHNIQUES FOR AERODYNAMIC CHARACTERIZATION AND PERFORMANCE EVALUATION AT HIGH ANGLE OF ATTACK [OUTILS POUR LA CARACTERISATION AERODYNAMIQUE ET L'EVALUATION DES PERFORMANCES A HAUTE INCIDENCE]
O. RENIER *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 13 p (SEE N94-34605 10-05) Mar. 1994 In FRENCH
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03
ONERA-IMFL develops techniques for high AOA maneuvering aircraft behavior studies. Specific wind-tunnels test coning and oscillatory coning motions, and constant pitch rate tests provide information about steady and unsteady, low speed aerodynamics.

Specific software facilitates data analysis and aerodynamic modelling. Application of nonlinear dynamic systems analysis techniques allows stabilities calculations and performance evaluation. For some maneuvers, behavior predictions can be validated with model flight tests in vertical wind-tunnel or in laboratory. These techniques have been used for forebody yaw control studies. Sensitivity of strakes efficiency to aircraft dynamic motions was measured in wind-tunnel facilities. Model flight tests confirm expected behaviors. Author (revised)

N94-34617# Tsentralni Aerogidrodinamicheskii Inst., Moscow (USSR).

AERODYNAMIC DESIGN OF SUPER MANEUVERABLE AIRCRAFT

R. D. IRODOV and A. V. PETROV *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 6 p (SEE N94-34605 10-05) Mar. 1994

(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03

The main peculiarities of aerodynamic design of highly maneuverable aircraft are examined. The possibilities of improving the aerodynamic characteristics of aircraft at high angles of attack by use of high-lift devices and powered-lift systems (boundary layer control, blowing over wing, engine thrust vectoring) are shown. The conditions of controllable maneuver at high post-stalled angles of attack (alpha is less than or equal to 90 degrees) are established. Results of experimental investigations on the influence of wing planform and locations of aircraft components (wing, empennage) on the longitudinal stability and controllability at high angles of attack are presented. A comparative analysis of aerodynamic and maneuver performance of aircraft of various configurations (conventional, three-surface, canard) is performed. Author (revised)

N94-34620# Naval Air Warfare Center, Patuxent River, MD. Strike Aircraft Test Directorate.

X-31 TACTICAL UTILITY: INITIAL RESULTS

DAVID E. CANTER and ALLEN W. GROVES *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 15 p (SEE N94-34605 10-05) Mar. 1994

(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

The X-31 is a research aircraft built to explore the tactical benefits of the enhanced fighter maneuverability that is possible through the use of thrust vectoring. This paper gives background information on the program and on the aircraft. The high angle of attack envelope expansion phase is covered. This section details aircraft modifications that were required. The tactical utility phase of testing, including simulation and flight testing, is discussed. Helmet mounted display and supersonic thrust vectoring tests planned for the near future are briefly discussed. Author (revised)

N94-34621# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. of Flight Mechanics.

EFA FLYING QUALITIES SPECIFICATION AND ITS UTILISATION

M. MARCHAND, R. KOEHLER, H. DUDA, E. BUCHACKER, and K. ELBEL *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 18 p (SEE N94-34605 10-05) Mar. 1994

(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

The European Fighter Aircraft (EFA) was designed as a highly augmented, basically unstable aircraft. Its Stability and Control System (FCS) is of a much higher complexity than that used in earlier aircraft, e.g., the Tornado. To ensure that safe operation and optimum performance are not degraded due to possible handling quality deficiencies, new methods had to be used for both the development and the assessment of the aircraft. This paper describes the specifications and the methods used in customer assessment prior to first flight. An overview of these methods is provided. Author (revised)

N94-34622# Naval Air Warfare Center, Warminster, PA. Air Vehicle and Crew Systems Technology Dept.

APPLICATION OF CURRENT DEPARTURE RESISTANCE CRITERIA TO THE POST-STALL MANOEUVERING ENVELOPE

ROBERT M. SELTZER and JEFFREY F. CALVERT *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 17 p (SEE N94-34605 10-05) Mar. 1994

(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

This paper presents an analysis of current departure resistance and high angle of attack (HAOA) flying quality parameters with respect to applicability and utility in the design and assessment of today's enhanced maneuverability aircraft. Modern fighter/attack aircraft possess extremely nonlinear aerodynamic databases and highly complex flight control systems. In addition, these aircraft require both departure resistance and mission effective HAOA maneuvering capability. The limitations of using traditional departure susceptibility parameters such as C(sub n(beta (sub DYN))) and LCDP to address departure resistance and agility design and analysis issues are analyzed and presented herein. Discussion includes the design philosophy and tradeoffs of improving static versus dynamic departure resistance. In addition, the utility of open or closed-loop departure parameters derived from linear and/or decoupled equations of motion representing highly nonlinear aircraft is addressed. Finally, a general methodology outlining the application and validity of current departure susceptibility parameters to the modern aircraft HAOA flight regime is provided with recommendations. Author (revised)

N94-34623# Wright Lab., Wright-Patterson AFB, OH. Flight Dynamics Directorate.

FLYING QUALITIES EVALUATION MANEUVERS

THOMAS J. CORD, DAVID B. LEGGETT, DAVID J. WILSON, DAVID R. RILEY, and KEVIN D. CITURS *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 8 p (SEE N94-34605 10-05) Mar. 1994

(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03

An initial set of aircraft maneuvers has been defined to augment the evaluation methods currently used by the flying qualities and flight test communities. These maneuvers are meant to employ the full range of available aircraft dynamics and to be applied over the full aircraft flight envelope. They include several closed-loop tasks and are the start of a set of demonstration maneuvers (of the type now used in the rotorcraft flying quality specification) for aircraft requirements. A primary goal was to establish a tie between design parameters, aircraft attributes, and the operational usage environment while maintaining control of the evaluation process. The approach was to concentrate on aircraft dynamics which occur in daily operations and to create pilot tasks which use those conditions to relate to important aircraft characteristics. Existing evaluation methods concentrate on comparing quantitative data to charts in MIL-Standards which predict flying qualities. The maneuvers discussed here directly measure the ability of the pilot to perform the tasks of interest and at the same time maintain a tie to the design community. Author (revised)

N94-34624# Army Aviation Systems Command, Moffett Field, CA.

STUDY FINDINGS ON THE INFLUENCE OF MANEUVERABILITY AND AGILITY ON HELICOPTER HANDLING QUALITIES

MATTHEW S. WHALLEY *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 10 p (SEE N94-34605 10-05) Mar. 1994

(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03

Three piloted simulation studies were performed by the U.S. Army Aeroflightdynamics Directorate to examine the influence of maneuverability and agility on helicopter handling qualities and to provide an expanded basis for the dynamic response requirements in Aeronautical Design Standard 33C, Handling Qualities Requirements for Military Rotorcraft. The experiments focused on aggressive tasks such as air-to-air combat and target acquisition and tracking. The first experiment focused on yaw agility requirements in the form of attitude quickness and bandwidth. The second experiment focused on pitch and roll agility and maneuverability requirements in the form of bandwidth, angular rate, and attitude quickness. The third experiment focused on maneuverability requirements in the form of normal and longitudinal load factor envelope for both conventional and compound

helicopters. Findings from the three studies are presented in the form of Cooper-Harper handling qualities ratings, pilot commentary, and task performance. Author

N94-34625# British Aerospace Defence Ltd., Preston (England).
OPERATIONAL AGILITY: AN OVERVIEW OF AGARD WORKING GROUP 19
K. MCKAY *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 11 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

The environment in which a fighter pilot is required to operate is subject to continual change. This change arises from advances in technology and the altering world political situation. The only prediction that can be made with any confidence is that this change process is bound to continue with an unpredictable rate. In dealing with change, it is easy to prescribe a process but extremely difficult to implement the process with success. Success requires anticipation, reaction, reevaluation and modification of tactics and processes. The need for change must be recognized and accommodated. Such an approach, whether applied to fighter airplanes or any field of human endeavor, translates to agility. In undertaking this work, the group encountered many definitions of agility, some of which represented widely differing viewpoints. Often, in the past, protagonists of the varying ideas have fallen into heated arguments as to who is right. Fortunately, within the group, we have been able to stand back and examine the arguments with a dispassionate approach which has enabled us to understand the various arguments and see the common ground, rather than the differences. From our deliberations and discussions, the answer has emerged that no one was wrong, that all were right, at least in part. However, few had taken the time to stand back and take an all embracing view. Had they done so, then the message that all were trying to put forward might have had a wider and more sympathetic audience. All of the agility concepts that have been put forward have some merit. What was required was a way to relate the ideas and be able to apply them in a manner that is both reasonable and logical from both the viewpoints of the designer/supplier of aircraft and the customer/user of the vehicles that result. In defining a weapon system, it is essential to examine the component parts and their interaction, whether this be airframe, propulsion system, sensors, cockpit and avionics, or the weapons themselves and establish balance and synergistic integration between all of the components appropriate to the intended role and missions of the aircraft. It is the need to achieve balance and integration that is the prime driver for understanding operational agility as a set of concepts, supported by metrics which fit into a generalized framework, capable of evaluating a complex combat aircraft design with a view to maximizing the effectiveness of that design within affordable cost limits. The activities of the group have produced such a framework, derived from the various flight mechanics based concepts, but which would appear to be generalizable to cover the other systems, either as individual systems, or as a total weapon system. There is further work required to confirm that this framework will stand, but our initial investigations are very promising. This points the way forward for future aircraft. Achievement of this design balance requires all of the weapon system attributes to be studied, evaluated, and weighed against each other, together with the cost implications, to determine the optimum solutions. This may imply significant compromises if the roles and perceived threats are too diverse. A consequence is that future design specifications and requirements will need to be prepared in a different way from that traditionally used. Author (revised)

N94-34626# Alenia, Turin (Italy).
OPERATIONAL AGILITY ASSESSMENT WITH THE AM-X AIRCRAFT
RENZO BAVA, UGO ROSSI, and SERGIO PALONI *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 19 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

Relating to the activities performed by WG 19 a common area of interest was individuated by Aermacchi, Alenia, and the Flight Test Center of the Italian Air Force to investigate the application of the agility concept to conventional aircraft. Agility metrics and maneuvers have been developed to evaluate the operational effectiveness of a modern fighter in the new combat scenarios that evolved following the introduction of advanced technologies. Agility metrics and maneuvers, however, may be effectively adopted to evaluate also operational effectiveness of a conventional aircraft since those metrics have been developed to reproduce synthetically the new operational scenarios. The AM-X ground attack aircraft was hence chosen as a testbed to verify the applicability of the agility concept to conventional aircraft and to assess the possible benefits for operational training. The research activity is being carried out by simulator and flight tests to compare simulator cueing effectiveness against the real A/C and to investigate simulator effectiveness for agility training. Single axis agility maneuvers performed by simulator will be validated through upcoming flight tests. Results from this activity will be used to plan and perform further simulation test with complex multiaxis closed loop agility tasks. This activity proved that agility metrics and maneuvers are applicable also to conventional A/C as well, and are effective in evaluating it within a highly dynamic combat environment. Operational agility may be improved with adequate pilot training and simulator may be used as an effective tool for it. Anyway, particular attention must be paid to the definition of the training program to overcome shortcomings of the simulator cueing system. Author (revised)

N94-34628# Defence Research Agency, Bedford (England).
THE INFLUENCE OF FLYING QUALITIES ON OPERATIONAL AGILITY
GARETH D. PADFIELD and JOHN HODGKINSON *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 14 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

Flying qualities standards are formally set to ensure safe flight and therefore to reflect minimum, rather than optimum, requirements. Agility is a flying quality but relates to operations at high, if not maximum, performance. While the quality metrics and test procedures for flying, as covered for example in MIL-STD-1797 or ADS33, may provide an adequate structure to encompass agility, they do not currently address flight at high performance. A current concern in both the fixed and rotary wing communities is the absence of substantiated agility criteria and the possible conflicts between flying qualities and high performance, i.e., more may not always be better. This paper addresses these concerns and suggests an agility factor that quantifies performance margins in flying qualities terms. The attitude quickness, from the latest rotary-wing handling requirements, provides an ideal agility measure and links handling with agility. A new parameter, based on maneuver acceleration, is introduced as a potential candidate for defining upper limits to flying qualities. These concepts are introduced within a framework aimed at unifying flying qualities and performance requirements. Finally, a probabilistic analysis of pilot handling qualities ratings is presented that suggests a powerful relationship between inherent airframe flying qualities and operational agility. Author (revised)

N94-34629# Aerospace Engineering Test Establishment, Cold Lake (Alberta).
AN AGILITY METRIC STRUCTURE FOR OPERATIONAL AGILITY
ANDREW REIF *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 15 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

This paper summarizes how an agility metric organizational structure was developed by the Flight Mechanics Panel Working Group 19. The structure was developed from existing concepts and was generalized for application to both fixed and rotary wing aircraft. The approach was based on time domain analysis concepts focusing on the 'time to complete' a specific operational task as the primary metric. From this metric a hierarchy of smaller time scale metrics were developed to emphasize the desired transient response dependent on the mission. The metric structure was developed for organizing the concepts of airframe agility as these were the most mature. The metric scheme is comprised of transient, experimental, and operational metrics. The transient metrics were defined as those time dependent parameters that characterize instantaneous airframe state changes. Experimental metrics were defined by discrete small task elements with compound properties that were optimized for evaluation purposes but were not necessarily recognizable as a mission related maneuver. Operational metrics were defined as complete mission task elements including the total vehicle response in multiple degrees

of freedom. The structure was also found to be applicable to other aspects of agility through the evolving concept of operational agility. This entailed the limited study of possible systems, pilot/vehicle interface, and weapon system time based agility metrics. Finally, the working group identified areas which required further study. Author (revised)

N94-36321# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

RECENT ADVANCES IN LONG RANGE AND LONG ENDURANCE OPERATION OF AIRCRAFT [LES PROGRES RECENTS DANS LE DOMAINE DES OPERATIONS AERIENNES A LONGUE DISTANCE ET DE LONGUE DUREE]

Nov. 1993 317 p In ENGLISH and FRENCH Symposium held in The Hague, Netherlands, 24-27 May 1993
(AGARD-CP-547; ISBN-92-835-0726-6) Copyright Avail: CASI HC A14/MF A03

Over the past few years, the use of aircraft in long range and/or long endurance operations has proved to be a successful use of military resources. Technologies which improve the range and endurance of aircraft have seen considerable advances over the past ten years. Aircraft design for these features has matured considerably while the procedure of air-to-air refuelling has made global deployment and 24+ hour operations a reality. This Symposium attempted to summarize the latest technological advances in the various fields which in a combined manner define the range and endurance of airborne vehicles, i.e.: airframe design technologies, including aerodynamic structures; propulsion technology; the human factors problems associated with these types of missions; and air-to-air refuelling technologies and procedures. For individual titles, see N94-36322 through N94-36347.

N94-36322# Wright Lab., Wright-Patterson AFB, OH.

HIGH ALTITUDE LONG ENDURANCE AIRCRAFT DESIGN STUDIES

V. B. VENKAYYA and V. A. TISCHLER *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 17 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A03/MF A03

This paper presents the results of structural optimization studies made on a High Altitude Long Endurance (HALE) aircraft at Wright Research and Development Center (now Wright Laboratory) during the late eighties. The purpose of this study is to investigate the feasibility of developing an ultralightweight airframe that can operate at high altitudes for extended periods of time in order to provide continuous reconnaissance, surveillance, communications and targeting functions. A variety of structural concepts and material studies were made prior to settling on a twin boom very high aspect ratio wing airframe. The wing and fuselage structures are made of truss substructures covered with skins, both made of high strength, high modulus, lightweight composite materials. Extensive structural optimization studies were conducted in order to obtain a lightweight structure. The large size of the aircraft drove the design to a stiffness critical structure. Author

N94-36323# Alenia Aeronautica, Turin (Italy). Preliminary Design Dept.

TECHNOLOGICAL CHALLENGES OF HIGH ALTITUDE LONG ENDURANCE UNMANNED CONFIGURATIONS

R. BARGETTO and R. SPEZZAFERRO *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 12 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A03/MF A03

This paper presents the conceptual work performed in Alenia during the recent years for defining some possible configurations for military and civil HALE (High Altitude Long Endurance) aircraft capable of carrying very different kinds of payloads and with mission durations ranging from one to two days. Also in relation to the aircrew fatigue implied by such a long flight time, they all have been conceived as UMA (UnManned Aircraft), achieving in that way a significant reduction of mass and complexity, withstanding the maturity of automatic control system. The aeromechanical aspect of the configurations (i.e aerodynamics, propulsion, structures, systems, weights and performances) will be discussed in detail considering that HALE-UMA type of aircraft have to face some technical challenges in many fields generated by the rather demanding requirements in terms of payload and endurance. Author

N94-36324# Aerospatiale, Toulouse (France). Aircraft Div.

FUTURE SUPERSONIC COMMERCIAL TRANSPORT AIRCRAFT: A TECHNOLOGICAL CHALLENGE FOR LONG HAUL TRAFFIC [AVION DE TRANSPORT SUPERSONIQUE FUTUR: UN DEFI TECHNOLOGIQUE POUR LE VOL LONG COURRIER]

J.-L. GALVANI *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 8 p (SEE N94-36321 11-05) Nov. 1993 In FRENCH
(AGARD-CP-547) Copyright Avail: CASI HC A02/MF A03

Long haul traffic is a key sector that is constantly increasing. Since Concorde entry into service in 1976, it has tripled and will again double by the end of the century. There is no doubt that this long haul traffic development will create an increasing interest in high speed. The entry into service of a HSCT will enable flight time to be divided at least by 2 on these long routes, and could capture 20 percent to 40 percent of the long range market. To face up this future air transport landscape Aerospatiale, who jointly with British Aerospace has accumulated an unique experience in high speed transport with the Concorde program, is studying a potential successor: the Alliance project cruising at Mach 2. Due to the significant progress in technology already achieved or foreseen in the near future, the entry into service of a second generation supersonic transport can be envisaged as early as 2005. The success of this project is strongly linked to the capability of the aircraft and the engine manufacturers to provide the appropriate technology level to make the airplane environmentally acceptable and economically attractive. A significant effort in R & D is necessary to make available the challenging technologies: new materials, aerodynamics, propulsion.... Considering the level of investment required and the complexity of the problems to be solved, a close collaboration involving industrial partners is necessary on a world wide basis. This collaboration has already started. Following a long experience of bilateral cooperation, Aerospatiale and British Aerospace joined again in 1990 to study together a second generation supersonic aircraft around their respective concepts (AST and Alliance). Both partners are also cooperating with DASA, Boeing, McDonnell Douglas, the Japanese Industries, Alenia and Tupolev within an International Study Group. Author

N94-36325# Naval Air Warfare Center, Warminster, PA. Aircraft Div.

THE CASE FOR SURFACE EFFECT RESEARCH, PLATFORM APPLICATIONS AND TECHNOLOGY DEVELOPMENT OPPORTUNITIES

J. M. L. REEVES *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 10 p (SEE N94-36321 11-05) Nov. 1993
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This paper commences by defining the conventional understanding of Surface Effect phenomenon and compares theories which show small reductions in drag occur above one span height above the surface. A discussion on reports of pilots who have flown their aircraft in surface effect ensues. From this, a broader understanding of surface effect is developed supported by low speed wind tunnel tests and Russian published technical documentation. The author divides surface effect platforms or, perhaps, better described as Enhanced Performance Low Flying Platforms (EPLFP's) into three distinct categories. Potential applications of surface effect platforms are discussed based on the changing world, the evolving airline industry and airport constraints. Missions and specific mission examples are given. Reasons for the pursuit of rather large platforms are presented as are some of the major technical hurdles which will have to be overcome for them to succeed. Technology opportunities are discussed. A summary concludes the paper. Author

N94-36326# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THE FUTURE OF LARGE CAPACITY/LONG RANGE MULTIPURPOSE AIR CARGO FLEETS [L'AVENIR D'AVIONS CARGOS MULTI-ROLES A LARGE CAPACITE ET GRAND RAYON D'ACTION]
PHILIPPE POISSON-QUINTON *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 8 p (SEE N94-36321 11-05) Nov. 1993 In FRENCH
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Both commercial and military aspects of Cargo Transport Aviation were discussed at the International Symposium organized by the French Aerospace Academy, held in March 1993 in Strasbourg. This paper summarizes some of the contributions and discussions dealing with the future role of the Air Cargo Transportation in relation to a global international policy of military and humanitarian intervention, including their technical and operational aspects. In a first part, the status of the World's Air Cargo activity is reviewed in terms of the main operational cargo airplanes, their capacity and their range, used both for commercial and military purposes; it includes the family of large cargos developed by Antonov in Ukraine and preliminary designs of huge cargo projects by the Russian laboratory TsAGI for 250 to 500 tons payload, and by NASA with spanloader or conventional schemes for intermodal containers transport. In a second part, the present U.S. Military Airlift forces are analyzed, with some comments on their recent global airlift deployment during the Gulf War. It is concluded that, as regards long term global policy, such existing task forces are totally inadequate to either stop immediately some local conflicts around the world, or to save population, in case of major natural or man-made disasters. That is why a much larger airlift system should be developed on an intergovernmental basis, the main objective would be its 'strategic efficiency' instead of a 'profit earning capacity', as used in commercial aviation. For that purpose, a 'supercargo' can be defined, developed and produced in the framework of an international consensus between the major aeronautical powers. Its size, configuration, operational characteristics and performance must be discussed, and a compromise agreed to cope with the main military and humanitarian missions; but such 'supercargo' airplane would be certainly much larger than the present ones, with two to four times their payload, and a transcontinental range capability; for their development, advantage would be taken of the best technologies that would become available in the next decade, and of the availability of design capability in the world's aircraft industry resulting from the present crisis. A flying wing configuration is suggested as a basis for a preliminary project. Finally, there is certainly a commercial spin-off of such massive supercargo production, if used to compete successfully with the surface transportation systems of large intermodal containers already used on major international markets. Author

N94-36327# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft.
OPTIMISATION OF COMPOSITE AIRCRAFT STRUCTURES BY DIRECT MANUFACTURING APPROACHES
G. BERCHTOLD and J. KLENNER *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 12 p (SEE N94-36321 11-05) Nov. 1993
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The present high performance aircraft designs are increasingly using high strength composite structures, mainly made of unidirectional carbon fiber tapes. But the composite technology is still afflicted with several weak points, e.g. the lack of adequate mechanized tape application techniques for complex compound structures, unsatisfying designs and design methods and missing continuous CAD/CAM-linkage. In this paper we will describe an 'Integrated Tape Laying System' (ITLS) which uses a new tape steering technology for automated manufacturing of complex parts. This system integrates the steering technology's potentials and restrictions completely in the design process to avoid time consuming iteration loops and to optimize the structure. To be able to understand the detailed process a short overview about two different geometry models demonstrated on a typical example will be given. From this the optimal detailed process will be derived, with an important influence from the specific manufacturing technology. Finally some remarks on economic potentials are outlined with their impact on typical composite aircraft parts related to different automated manufacturing techniques. Author (revised)

N94-36330# Westland Helicopters Ltd., Yeovil (England).
EH101: A NEW HELICOPTER CAPABLE OF LONG RANGE MISSIONS
C. J. BATTISSON and H. E. TATTON-BROWN *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 10 p (SEE N94-36321 11-05) Nov. 1993
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The EH101 is a new medium helicopter being produced by EH Industries, a company jointly owned by Agusta of Italy and Westland of the UK. The aim of this presentation is to explore the roles in which the EH101 will be called upon to cover long ranges and examine its suitability for these roles. The roles which will be examined fall into the following categories: search and rescue, self-ferry, and special operations. The successful completion of such missions will demand particular capabilities of the crew and the machine. The following aspects of aircraft design will be looked at with respect to the EH101: in-flight refuelling, all-weather capability, maintenance requirements, and crew environment. Because of the wide ranging nature of the subject and the limited time available this is intended to examine only the key points required for these roles and capabilities. Author (revised)

N94-36331# Eurocopter France, Marignane (France).
THE CONVERTIBLE (HELICOPTER/AIRPLANE) EUROFAR: GENERAL CONSIDERATIONS ON THE TECHNICAL PROGRESS AND ON FUTURE ADVANCES [LE CONVERTIBLE TYPE EUROFAR: VUE D'ENSEMBLE DES AVANCEMENTS TECHNIQUES ET MISSIONS FUTURES]
A. MARTINI and J. RENAUD *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p (SEE N94-36321 11-05) Nov. 1993 In FRENCH
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Until the last few years, the idea of a convertible aircraft did not progress into testing because the available technology did not satisfy the cost/efficiency parameters, and because the need for such an aircraft was not felt. Today, conditions are different. Strategic necessities and technical progress have created an atmosphere in the United States and in Europe where this old dream of engineers may be resurrected. Author

N94-36332# Aerospatiale, Toulouse (France). Aerodynamics Conception Dept.
CALCULATIONS USED TO OPTIMIZE THE INSTALLATION OF CIVIL AIRCRAFT ENGINES [UTILISATION DES METHODES DE CALCUL POUR OPTIMISER L'INSTALLATION MOTRICE DES AVIONS DE TRANSPORT]
X. MONTHUS, PH. COLIN, PH. MOGILKA, and A. MOLBAY-ARSAN *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 31 p (SEE N94-36321 11-05) Nov. 1993 In FRENCH
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Within the research program on AIRBUS, the Aerodynamics Conception Department of Aerospacial Avions is responsible for the research on the aerodynamics of the reactor's pylon, air inlet (or technical evaluation on the system provided by the constructor) and for the optimization of aerodynamics in the ensemble of the engine installation. This includes studies on minimizing undesirable effects (loss of carrying capacity, increase in drag) due to the interaction between wings, pylon, and engine pod. This article lists the various tools used by the above department in order to fulfill its task: the C.A.O. system, principally conceived for aerodynamics concerns, the surface and volume representation systems as well as the main systems of 3D calculations on complex geometric arrangements. Three recent applications of these methods are presented within the framework of the development of the AIRBUS A330/A340 aircraft, and associated systems: air flow in the zone of pylon/wing intersection; effects due to the size of the engine in comparison to given wing characteristics and modelization of the jet's effect; and orientation of relationship between engine thrust and aircraft. Author

N94-36340# Aerospace Engineering Test Establishment, Cold Lake (Alberta).
FLIGHT TEST CERTIFICATION OF A 480 GALLON COMPOSITE FUEL TANK ON CF-18
MARIO B. J. LAGRANGE *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 22 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A03/MF A03

The Aerospace Engineering Test Establishment (AETE), as the Canadian Forces (CF) flight test authority, has recently completed flight tests and analysis of a major store certification program to establish an operational flight envelope for the carriage and jettison of a newly designed 480 gallon external fuel tank (EFT) for the CF-18 aircraft. The certification process involved a progressive series of analysis, wind tunnel tests, qualification tests, ground tests, and flight test activities. Most of the preflight activities were performed by the designer, McDonnell Aircraft Company (McAir), while all flight testing was the responsibility of AETE with engineering support from McAir. The progression of events from the qualification testing to the final flight testing recommendations are summarized herein. The primary focus of this paper is on the flying activities such as flutter, loads, stability and control, separation/jettison, and performance. Special instrumentation, flight test techniques, and test concept philosophy are also discussed. This paper highlights various technical problems encountered, such as the near flutter onset condition observed with tanks 50 percent full, the premature failure of the inboard wing spar pylon receptacle discovered after the last maneuvering loads flight, and the localized pitchup phenomena observed during stability and control (S&C) testing. A glance at the increased range and payload capabilities is also included. Overall, the 480 gallon EFT was determined to be a viable option for the CF-18 aircraft. Author

N94-36341# Dassault Aviation, Saint-Cloud (France). Direction Generale Technique.
IN-FLIGHT REFUELING: DASSAULT AVIATION RESEARCH ON THE RAFALE AIRCRAFT [RAVITAILLEMENT EN VOL L'EXPERIENCE DE DASSAULT-AVIATION APPLIQUEE AU RAFALE]
CHARLES DEFREVILLE *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 11 p (SEE N94-36321 11-05) Nov. 1993 In FRENCH
(AGARD-CP-547) Copyright Avail: CASI HC A03/MF A03

The Rafale is the latest combat aircraft built by Dassault Aviation. It is equipped with an in-flight refueling system using a fixed pole. This article relates the important steps taken during its conception and the various technologies that were used: structure, aerodynamics, systems, etc. The second part of the article describes the testing that was conducted in-flight as well as on the ground, making it possible to corroborate the performance of the systems and the flight characteristics of this aircraft. Transl. by FLS

N94-36342# Frontier Technology, Inc., Beavercreek, OH.
FUTURE TANKER CONSIDERATIONS AND REQUIREMENTS
LAVON JORDAN and MICHAEL KRIMMER *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A02/MF A03

Starting seven years ago, the USAF Aeronautical Systems Center began analyzing future tanker system requirements and developing plans for satisfying these requirements. Frontier Technology, Inc. (FTI) supported the USAF in four of the efforts. Frontier has completed one KC-135 multipoint analysis and is currently doing a second one. The completed effort determined: the pros and cons of hose-drogue refueling and the best fuel pumping rate for the KC-135 using two wing air refueling pods. The current job involves a more in-depth, overall assessment of operational needs, concepts of operation, and alternative wing pods. It emphasizes compatibility with Allied and U.S. Navy aircraft receivers. Frontier Technology is presenting two related papers at this AGARD symposium. This paper covers the rationale and requirements for multipoint refueling. It covers trends and future employment of aerial refueling tankers, as well as the increasing importance of interoperability. Derived from text

N94-36343# Naval Air Warfare Center, Patuxent River, MD. Flight Test and Engineering Group.
AERIAL REFUELING INTEROPERABILITY FROM A RECEIVER FLYING QUALITIES PERSPECTIVE
D. J. LUDWIG *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A02/MF A03

Over the past decade, there has been increased emphasis on interservice and international operability with respect to aerial refueling (AR). One area concerning interoperability that needs to be considered in light of the increased trend towards large multipoint tankers is receiver flying qualities during AR. This paper stresses the importance of conducting receiver proximity trials to optimize refueling position behind the tanker and providing the pilot with the best receiver flying qualities for AR that can be attained. Receiver flying qualities behind the tanker can be seriously degraded if proper steps to optimize receiver refueling positions are not taken prior to final design. Poor receiver flying qualities in the refueling positions can reduce engagement success rate, increase the amount of training required, increase mishaps, increase refueling cycle time and seriously degrade mission effectiveness of the tanker. There are, of course, many other considerations regarding tanker/receiver compatibility such as airspeed/altitude compatibility, fuel system compatibility, communications, night lighting, etc. But this paper primarily addresses receiver flying qualities and the importance of refueling position behind the tanker as it pertains to flying qualities. Specific programs discussed are Navy trials with the Air Force KC-10 and KC-135 tankers and Navy programs to bring a wing pod tanker capability to the P-3 airplane. Additionally, efforts underway to enhance tanker mission effectiveness of the KC-130 with a variable geometry drogue are discussed and their ramifications explored. Author

N94-36344# McDonnell-Douglas Aerospace, Long Beach, CA. Transport Aircraft.
TANKER SYSTEM AND TECHNOLOGY REQUIREMENTS DEFINITION: A TANKER TECHNOLOGY ROAD MAP
JOHN KORIAGIN and BERTON B. RUND *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 12 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A03/MF A03

This paper presents a process that leads from comprehensive tanker system requirements analysis to the development of a technology 'road map.' This road map is a matrix listing key technology requirements for future air refueling tanker aircraft capabilities and the current status of research and development activities in these key areas. Generalized examples from material prepared under a U.S. Air Force Contracted Research and Development (CRAD) study are utilized. Multimission capabilities (i.e., tanker, and cargo and passenger transport) are often preferred for these new aircraft. This allows the flexibility of use for many purposes besides that of just air refueling: military cargo and passenger deployments, humanitarian relief, medical air evacuation, executive transport, etc. For this reason these tankers are often referred to as 'tanker/transports' to emphasize these capabilities. In this paper, the term 'tanker' is used to describe what in all likelihood will be a tanker/transport. Author (revised)

N94-36345# Frontier Technology, Inc., Beavercreek, OH.
HOSE-DROGUE VERSUS BOOM RECEPTACLE AIR REFUELING
DONALD COPELAND and THOMAS MCCONNELL *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 6 p (SEE N94-36321 11-05) Nov. 1993
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The basis of this paper is analyses performed by Frontier Technology, Inc. for the USAF. Frontier has performed evaluations of multiple tanker candidates to supplement and to eventually replace the KC-135 tanker fleet. The analyses included tanker refueling support for six mission areas: theater employment of combat fighter aircraft, intercontinental fighter deployments, extended offshore range of naval carrier operations, intercontinental airlift, North American air defense, and long range nuclear warfare. The characteristic airborne refueling needs of the six missions are somewhat different. The first mission listed, theater employment of combat fighter aircraft, is characteristically different from the

other areas in that it stresses the need to refuel more aircraft over shorter periods of time than the other five mission demands except for some situations in air defense support. In theater employment operations the demands of the larger tanker aircraft are stressed the most when waves of aircraft attack during short periods of time in the attempt to overwhelm enemy defenses. This tanker demand is in contrast to that of the nuclear warfare mission which requires large amounts of fuel for a single receiver (bomber) aircraft on a lengthy mission where the precise refueling time is not critical. Author (revised)

N94-36346# Royal Netherlands Air Force, The Hague (Netherlands). Training and Transport Aircraft and Helicopter Div.

THE KDC-10 PROGRAMME OF THE ROYAL NETHERLANDS AIR FORCE

PAUL R. BRINKGREVE *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 6 p (SEE N94-36321 11-05) Nov. 1993

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Replacement of the RNLAF F-27 transport fleet, first mooted in 1984, became a serious option a few years later because of a growing need for AAR capacity. Years of discussion and market research resulted in a requirement for (among others) two DC-10 aircraft to be modified into tanker/transport aircraft. The budget was not sufficient to develop new KMD-11 tanker aircraft, nor did it allow buying existing tanker aircraft. On the basis of earlier programs from other countries, involving different aircraft, RNLAF decided that it should be possible to modify two DC-10 aircraft into so-called KDC-10 aircraft. With assistance from McDonnell Douglas Aircraft (MDA), four aircraft were selected on the basis of a number of criteria. These aircraft were studied thoroughly. On the basis of condition and price two Martinair DC10-30 CF aircraft were purchased on 30 June 1992. These will be modified into KDC-10 tanker/transport aircraft. The RNLAF contracted MDA to study feasibility, timetable, and cost of modifying two (Martinair) DC-10-30 CF aircraft into tanker/transport aircraft. The study concluded that the program was feasible within the proposed time frame, given that USAF would cooperate. Also the total cost estimate could be kept within budget. It was not possible to keep the KC-10 Aerial Refuelling Operator (ARO) station, so a new Remote Aerial Refuelling Operator (RARO) station will have to be developed. The design, however, is not completely new as it has been implemented on other aircraft. The RNLAF expects the first KDC-10 aircraft to be in service by January 1995, the second to follow approximately three months later. Based on this, the modification of the first aircraft is scheduled to start on 1 July 1994 and the second in December 1994. Development of the modification program has already begun. USAF has been requested to assist RNLAF in program management, contracting, and purchasing of certain parts. Author

N94-36347# Aerospace Engineering Test Establishment, Cold Lake (Alberta). Flight Dynamics.

CC-130H(T) TACTICAL AERIAL REFUELLING TANKER DEVELOPMENT FLIGHT TEST PROGRAMME

ANDREW REIF and MARC TREMBLAY *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 16 p (SEE N94-36321 11-05) Nov. 1993

(AGARD-CP-547) Copyright Avail: CASI HC A03/MF A03

This paper describes the development flight test program for the CC-130H(T) Tactical Aerial Refuelling Tanker. The Canadian operational requirement is first described, followed by a detailed discussion of the test item, receiver aircraft, and the ground/flight test method and preliminary results. The development is significant since it represents the first certification of the Flight Refuelling Limited Mk 32B refuelling pods on a Hercules aircraft. Further flight testing to be conducted in the near future are also mentioned. Author

N94-36618# Dornier-Werke G.m.b.H., Friedrichshafen (Germany).

LANDING OF AN UNMANNED HELICOPTER ON A MOVING PLATFORM. HIGH ACCURACY NAVIGATION AND TRACKING

HANS-PETER ENGELBERT and JOHANNES SCHROEDER *In* AGARD, Pointing and Tracking Systems 9 p (SEE N94-36616 12-18) May 1994

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Drones are of great importance for reconnaissance and surveillance in military applications. In regard to maritime drones Dornier demonstrated the automatic landing of a drone on a moving ship motion simulator in December 1991. The landing accuracy is determined by the tracking process. The tracking is performed by a laser tracker, which measures the drone position relative to the ship. Not only the drone but also the ship is equipped with an INS (Inertial Navigation System). The landing computations are performed in earth-fixed coordinates, whereby the earth-fixed positions are delivered by the INS. The determination of the drone position results from a combination of measurement values from the airborne INS and data from the ship laser tracker. The combination of the different information in the drone is performed in a Kalman-filter. The concept was verified in an experimental program. During the experimental program 13 flights were performed. The tracking accuracy was approximately 0.2 m. Author

N95-14102# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

IDENTIFICATION OF DYNAMIC SYSTEMS. VOLUME 3: APPLICATIONS TO AIRCRAFT. PART 2: NONLINEAR ANALYSIS AND MANOEUVRE DESIGN [L'IDENTIFICATION DES SYSTEMES DYNAMIQUES: APPLICATIONS AUX AERONEFS. TITRE 2: L'ANALYSE NON-LINEAIRE ET LA CONCEPTION DE LA MANOEUVRE]

J. A. MULDER (Technische Univ., Delft, Netherlands.), J. K. SRIDHAR (Technische Univ., Delft, Netherlands.), and J. H. BREEMAN (National Aerospace Lab., Amsterdam, Netherlands.) May 1994 213 p Flight Test Techniques Series

(AGARD-AG-300-VOL-3-PT-2; ISBN-92-835-0748-7) Copyright Avail: CASI HC A10/MF A03

This AGARDograph is a sequel to the previous AGARDographs published in the AGARD Flight Test Techniques Series, Volume 2 on 'Identification of Dynamic Systems' and Volume 3 on 'Identification of Dynamic Systems - Applications to Aircraft - Part 1: The Output Error Approach' both written by R.E. Maine and K.W. Iliff. The intention of the present document is to cover some of those areas which were either absent or only briefly mentioned in those volumes. These areas are Flight Path Reconstruction, Nonlinear Model Identification, Optimal Input Design and Flight Test Instrumentation. The present approach to identification is rather different from that presented in the earlier AGARDographs in the sense that the identification problem is decomposed into a state estimation and a parameter identification part. This approach is referred to as the Two-Step Method (TSM), although one will find other names like Estimation Before Modelling (EBM) in the literature. It will be shown in the present AGARDograph that this approach has significant practical advantages over methods which no attempt is made to decompose the joint parameter-state estimation problem. The two-step method is generally applicable to flight vehicles such as fixed wing aircraft and rotorcraft which are equipped with state of the art inertial reference systems. The theoretical developments in the present AGARDograph will be illustrated with examples of a flight test program with the De Havilland DHC-2 Beaver aircraft, the experimental aircraft of the Delft University of Technology which has been used for almost two decades to test new ideas in the science of aircraft parameter identification. Author

N95-16562# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
OPTIMUM DESIGN METHODS FOR AERODYNAMICS [LES METHODES DE CONCEPTION OPTIMALE POUR L'AERODYNAMIQUE]
Nov. 1994 270 p Special course held in Rhode-Saint-Genese, Belgium, 25-29 Apr. 1994; sponsored by AGARD and VKI
(AGARD-R-803; ISBN-92-836-1007-5) Copyright Avail: CASI HC A12/MF A03

The course addresses the ingredients of new algorithms for accurate and cost effective numerical solutions of design problems. A special emphasis is given to the following topics: fundamental mathematical properties of methodologies for solving optimization problems using control theory and variational formulations; numerical aspects of fast algorithms coupling constrained optimizers and flow analysis solvers and their implementation; geometric representations and choice of design variables; and real life 3-D applications encountered in Aerospace Engineering in order to demonstrate the usefulness of these design methodologies to practical design problems. For individual titles, see N95-16563 through N95-16573.

N95-16565# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
OPTIMUM AERODYNAMIC DESIGN VIA BOUNDARY CONTROL
ANTONY JAMESON *In* AGARD, Optimum Design Methods for Aerodynamics 33 p (SEE N95-16562 04-05) Nov. 1994
Sponsored in cooperation with USRA
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(AGARD-R-803) Copyright Avail: CASI HC A03/MF A03

These lectures describe the implementation of optimization techniques based on control theory for airfoil and wing design. In previous studies it was shown that control theory could be used to devise an effective optimization procedure for two-dimensional profiles in which the shape is determined by a conformal transformation from a unit circle, and the control is the mapping function. Recently the method has been implemented in an alternative formulation which does not depend on conformal mapping, so that it can more easily be extended to treat general configurations. The method has also been extended to treat the Euler equations, and results are presented for both two and three dimensional cases, including the optimization of a swept wing. Author

N95-16566# National Aerospace Lab., Amsterdam (Netherlands). Theoretical Aerodynamics Dept.
RESIDUAL-CORRECTION TYPE AND RELATED COMPUTATIONAL METHODS FOR AERODYNAMIC DESIGN. PART 1: AIRFOIL AND WING DESIGN
TH. E. LABRUJERE *In* AGARD, Optimum Design Methods for Aerodynamics 24 p (SEE N95-16562 04-05) Nov. 1994
(AGARD-R-803) Copyright Avail: CASI HC A03/MF A03

The present paper discusses the problem of inverse shape design, where the geometry of a wing should be determined such that it will have a prescribed surface pressure distribution at the design condition considered. A survey is given of so-called decoupled-solution methods or this problem. With this type of methods the flow field around a current estimate of the wing and a subsequent new estimate of the wing are determined by two separate computational steps in an iterative process. A global description is given of the main features of the underlying theories and some examples of application are given. A detailed description is given of the NLR method for inverse shape design based on the residual-correction approach. Author

N95-16567# National Aerospace Lab., Amsterdam (Netherlands). Theoretical Aerodynamics Dept.
RESIDUAL-CORRECTION TYPE AND RELATED COMPUTATIONAL METHODS FOR AERODYNAMIC DESIGN. PART 2: MULTI-POINT AIRFOIL DESIGN
TH. E. LABRUJERE *In* AGARD, Optimum Design Methods for Aerodynamics 31 p (SEE N95-16562 04-05) Nov. 1994
(AGARD-R-803) Copyright Avail: CASI HC A03/MF A03

The present paper considers the problem of multi-point airfoil design, where the geometry of an airfoil is to be determined such that it will approximate simultaneously, at different design points, a priori specified aerodynamic requirements. Some attention is paid to approaches published in the open literature. The main part of the paper concerns work in progress at NLR. Some preliminary results are shown. Author

N95-16568# Paris VI Univ. (France). Lab. Analyse Numerique.
OPTIMAL SHAPE DESIGN FOR AERODYNAMICS
O. PIRONNEAU *In* AGARD, Optimum Design Methods for Aerodynamics 38 p (SEE N95-16562 04-05) Nov. 1994
(AGARD-R-803) Copyright Avail: CASI HC A03/MF A03

After a brief recall on the history of the field of optimal shape design, we shall present a few applications to aerodynamics, then recall the variational approach, the numerical methods and the recent developments both in applied mathematics and in computer sciences. Author

N95-16569*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AIRFOIL OPTIMIZATION BY THE ONE-SHOT METHOD
G. KURUVILA (Vigyan Research Associates, Inc., Hampton, VA.), SHLOMO TAASAN (Institute for Computer Applications in Science and Engineering, Hampton, VA.), and M. D. SALAS *In* AGARD, Optimum Design Methods for Aerodynamics 21 p (SEE N95-16562 04-05) Nov. 1994
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An efficient numerical approach for the design of optimal aerodynamic shapes is presented in this paper. The objective of any optimization problem is to find the optimum of a cost function subject to a certain state equation (Governing equation of the flow field) and certain side constraints. As in classical optimal control methods, the present approach introduces a costate variable (Language multiplier) to evaluate the gradient of the cost function. High efficiency in reaching the optimum solution is achieved by using a multigrid technique and updating the shape in a hierarchical manner such that smooth (low-frequency) changes are done separately from high-frequency changes. Thus, the design variables are changed on a grid where their changes produce nonsmooth (high-frequency) perturbations that can be damped efficiently by the multigrid. The cost of solving the optimization problem is approximately two to three times the cost of the equivalent analysis problem. Author

N95-16570# Deutsche Airbus G.m.b.H., Bremen (Germany). Aerodynamic Design Section.
TOOLS FOR APPLIED ENGINEERING OPTIMIZATION
A. VANDERVELDEN *In* AGARD, Optimum Design Methods for Aerodynamics 10 p (SEE N95-16562 04-05) Nov. 1994
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This paper is an introduction to applied optimization of engineering problems, with an emphasis on aircraft design. First, the optimization problem is described-namely, the objective function and the problems often involved in its optimization, the variables or parameters over which the objective function is optimized, and the constraints upon the objective function. Formulation of the optimization problem to ensure rapid and accurate convergence is discussed and illustrated with specific examples. Three classes of optimization methods: evolution, downhill simplex and gradient optimization, are discussed. The robustness and speed of these optimization methods are evaluated and compared. Finally, a number of practical implementation issues related to optimization are highlighted. Author

N95-16571# Deutsche Airbus G.m.b.H., Bremen (Germany). Aerodynamic Design Section.
THE GLOBAL AIRCRAFT SHAPE
A. VANDERVELDEN *In* AGARD, Optimum Design Methods for Aerodynamics 11 p (SEE N95-16562 04-05) Nov. 1994
(AGARD-R-803) Copyright Avail: CASI HC A03/MF A03

This work describes the methodology used to compare supersonic design concepts and its use in industry. The design concepts are analyzed with a modular synthesis model and compared on the basis of operating economy with specified performance and environmental impact. The analysis routines of the synthesis model are mainly configuration independent and represent fixed levels of structural, aerodynamic and propulsion technology. The specialist departments are responsible for the content of the routines, and later verify the design with more refined methods. At present more than two hundred variables describe the aircraft geometry, engine characteristics and mission.

More than twenty of those variables representing the aircraft and its flight-profile are optimized simultaneously as a function of Mach number, payload and range. Because the various designs are analyzed with the same routines and optimization procedures they can be easily compared. This aircraft pre-optimization results in a significant reduction of the number of follow-on detail-design cycles, especially for non-conventional designs. Author

N95-16572# Deutsche Airbus G.m.b.H., Bremen (Germany). Aerodynamic Design Section.
AERODYNAMIC SHAPE OPTIMIZATION
A. VANDERVELDEN *In* AGARD, Optimum Design Methods for Aerodynamics 13 p (SEE N95-16562 04-05) Nov. 1994
(AGARD-R-803) Copyright Avail: CASI HC A03/MF A03

This paper will discuss examples of aerodynamic shape optimization at Deutsche Airbus in Bremen. First, we will introduce a general approach to aerodynamic shape design based on minimization of aircraft life energy costs. Realistic constraints are introduced on lift, pitching moments and thickness. This method is applied to the quasi-3D design of multipoint transonic wings which are analyzed by a full potential code with a coupled boundary layer calculation. Finally, this method is applied to the wing-body design of a Supersonic Civil Transport that is analyzed with a linear potential code with real flow corrections and a decoupled boundary layer calculations. Author

N95-16573# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
REVIEW OF THE EUROPT PROJECT AERO-0026
B. MANTEL, J. PERIAUX, and B. STOUFFLET *In* AGARD, Optimum Design Methods for Aerodynamics 43 p (SEE N95-16562 04-05) Nov. 1994
(Contract(s)/Grant(s): BRITE-EURAM-AERO-0026)
(AGARD-R-803) Copyright Avail: CASI HC A03/MF A03

Despite progress toward automated shape design in Industry has been penalized until now by excessive computing costs, useful innovative design methodologies have been recently proposed for computing different academic and industrial designs of nozzles, airfoils and wing-body combinations operating in inviscid flows modelled by the potential and Euler equations. Since the designer has a precise idea of the pressure distribution that will produce the desired performance, not only optimization problems but also inverse problems have to be considered in current design. The goal of this lecture is to describe the major ingredients of new algorithms developed by european partners of the AERO 89-0026 project, which allow accurate and cost effective numerical solutions of optimization problems and also to illustrate the capabilities of design software on test cases proposed in a Workshop for validation purpose. Industrial applications illustrating these methodologies are also presented. Finally a new emergent search method for non linear optimization problems provided by simple Genetic Algorithms (GA's) is briefly described and illustrated by a few examples related to inverse problems and applied to reduction of viscous drag. Author

N95-17863# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Entwurfsaerodynamik.
DLR-F4 WING BODY CONFIGURATION
G. REDEKER *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 21 p (SEE N95-17846 04-02) Aug. 1994
(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

These tests have been carried out under the auspices of GARTEUR in order to provide an experimental data base for a modern commercial transport type aircraft against which results of various computational methods may be checked. The tests were carried out in three major European wind tunnels (NLR-HST, ONERA-S2MA, and DRA-8ft x 8ft DRA Bedford) in order to compare the results of the same model in different wind tunnels. For the purpose of these tests the available geometry of the DLR-F4 model of a wing body configuration, which was developed as a research configuration of a modern transport type aircraft, was selected by the GARTEUR Action Group AD (AG01) 'Wing body aerodynamics at transonic speeds.' Derived from text

N95-18599# Aerospatiale, Toulouse (France). Dept. Etudes Generales-Structures.
GYROSCOPIC AND PROPELLER AERODYNAMIC EFFECTS ON ENGINE MOUNTS DYNAMIC LOADS IN TURBULENCE CONDITIONS [EFFETS GYROSOPIQUES ET AERODYNAMIQUES DES PROPULSEURS SUR LES CHARGES DES MOTEURS D'AVIONS EN CONDITIONS TURBULENTES]
J. M. SAUCRAY *In* AGARD, Aircraft Loads due to Turbulence and their Impact on Design and Certification 12 p (SEE N95-18597 05-08) Dec. 1994 In FRENCH
(AGARD-R-798) Copyright Avail: CASI HC A03/MF A01

This paper deals with the problem of calculating loads on engines and their supporting structures when inertial characteristic, high engine speeds, large displacements, imposed by extreme atmospheric disturbances, give an important impact of gyroscopic effect. A direct method integrating the gyroscopic action in Lagrange's equations as a function of the polar moment of inertia, engine revolution speed and precession speed is presented and compared to the more common practice of superimposing gyroscopic effects on the basis of the angular speed calculated at the engine center of gravity. The results establish a good correlation between the two method on pitch and yaw moments on engine. On the other hand, transfer function modifications due to gyroscopic effects generate an increase of other loads for the direct method calculations, for both the turboprop and the turbojet aircraft. Effects of the aerodynamic force of the propeller due to the engine response are also examined. Author

N95-18601# Construcciones Aeronauticas S.A., Madrid (Spain). Structural Dynamics Dept.
A STUDY OF THE EFFECT OF STORE UNSTEADY AERODYNAMICS ON GUST AND TURBULENCE LOADS
M. OLIVER, J. CASALENGUA, C. MADERUELO, Y. CAMACHO, and H. CLIMENT *In* AGARD, Aircraft Loads due to Turbulence and their Impact on Design and Certification 12 p (SEE N95-18597 05-08) Dec. 1994
(AGARD-R-798) Copyright Avail: CASI HC A03/MF A01

Gust and turbulence loads are the most severe conditions for some parts of the aircraft, especially in the outboard wing region. The addition of external stores usually alleviates the gust/turbulence loads on the wing but becomes critical for other components as pylons and wing/pylon attachments. Safety implications and all-weather envelope of current fighters force an accurate study of the gust/turbulence response of the aircraft for each store configuration. Inertia is the most important contribution of the store to the gust/turbulence loads. Nevertheless, store unsteady aerodynamics should be included if significantly changes the results of the gust/turbulence response. This paper is devoted to the analytical study of the effect of store unsteady aerodynamics on gust/turbulence response. A large number of configurations have been included in the study. Several regulations to define the gust/turbulence excitation have been used. Author

N95-18602# McDonnell-Douglas Aerospace, Long Beach, CA. Transport Aircraft.
COMPARISON OF STOCHASTIC AND DETERMINISTIC NONLINEAR GUST ANALYSIS METHODS TO MEET CONTINUOUS TURBULENCE CRITERIA
PATRICK J. GOGGIN *In* AGARD, Aircraft Loads due to Turbulence and their Impact on Design and Certification 12 p (SEE N95-18597 05-08) Dec. 1994
(AGARD-R-798) Copyright Avail: CASI HC A03/MF A01

Current continuous turbulence Power Spectral Density (PSD) gust analysis methods are valid only for linear aircraft. In the past, many methods for the analysis of nonlinear aircraft to meet the current PSD gust criteria have been proposed. In this paper, three stochastic simulation based and one deterministic function based methods are compared and evaluated for the compliance of nonlinear aircraft to the current continuous turbulence gust criteria. The aircraft configurations analyzed in this paper include a symmetric aircraft model coupled to a nonlinear gust load alleviation (GLA) system and an anti-symmetric aircraft model coupled to a nonlinear yaw damper system. Results from these four nonlinear methods are compared to linear closed and open-loop results as well as currently used linear approximation methods. Computing performance issues are addressed to provide the reader with a complete picture of the trade-off between the analysis' accuracy and computing cost. Author

N95-18603# Cessna Aircraft Co., Wichita, KS. Aircraft Structural Integrity Dept.
DESIGN LIMIT LOADS BASED UPON STATISTICAL DISCRETE GUST METHODOLOGY
D. L. HULL *In* AGARD, Aircraft Loads due to Turbulence and their Impact on Design and Certification 8 p (SEE N95-18597 05-08) Dec. 1994
(AGARD-R-798) Copyright Avail: CASI HC A02/MF A01

Statistical Discrete Gust (SDG) methodology for extreme turbulence provides the basis of a design criterion that accounts for: (1) the statistical nature of design level turbulence; (2) the effects of lightly damped aircraft responses; (3) critical responses that may have significant frequency separation; and (4) the effects of nonlinear control systems. The criterion would eliminate the need for multiple design criteria and could increase the structural efficiency of new aircraft. The increased efficiency would be the result of having equally probable design limit loads for all gust critical components of the aircraft. Author

N95-18605*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SPECIAL EFFECTS OF GUST LOADS ON MILITARY AIRCRAFT
JOHN C. HOUBOLT *In* AGARD, Aircraft Loads due to Turbulence and their Impact on Design and Certification 7 p (SEE N95-18597 05-08) Dec. 1994
(AGARD-R-798) Copyright Avail: CASI HC A02/MF A01

In the operation of airplanes, atmospheric turbulence creates a broad spectrum of problems. The nature of these problems is presented in this paper. Those that are common to both the commercial carriers and to the military fleet are discussed first. Attention is then focused on the problems that are of special concern in military operations. An aim is to bring out the need for continued effort in the gust research area. Author

N95-19151# Wright Lab., Wright-Patterson AFB, OH.
NONLINEAR DYNAMIC RESPONSE OF AIRCRAFT STRUCTURES TO ACOUSTIC EXCITATION
H. F. WOLFE and R. G. WHITE (Southampton Univ., England.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 10 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

Acoustic fatigue failure in aerospace structures has been a concern for many years. New prediction techniques are needed for the new materials and structural concepts of interest and higher sound pressure levels encountered. The objective of this program of work is to improve the fundamental understanding of the nonlinear behavior of beams and plates excited from low to high levels of excitation. Experiments have been conducted utilizing a clamped-clamped (C-C) beam statically tested and shaker driven at increasing levels of excitation. Similarly, C-C-C-C plates were excited by a vibration shaker and in a progressive wave tube. The total strains and the components, bending and axial, and the displacements were measured with increasing levels of excitation. Bistable behavior was observed with sinusoidal excitation for both the beams and plates. The measured axial or membrane strains were very low compared to the bending strains for high levels of excitation. The beams randomly excited exhibited a slight frequency shift and peak broadening, which can be attributed to an increased stiffening or hard spring nonlinearity. The plates randomly excited exhibited a greater frequency shift and peak broadening than the beams. The dynamic tests resulted in a nonlinear relationship between the response strains and displacements and the excitation levels. A multimodal model is discussed to estimate the mean square stress response due to high levels of excitation. Author

N95-19154# Wright Lab., Wright-Patterson AFB, OH.
MODELLING STRUCTURALLY DAMAGING TWIN-JET SCREECH
MARY KAE LOCKWOOD, STEVEN H. WALKER, and ALAN B. CAIN (McDonnell-Douglas Corp., Saint Louis, MO.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 8 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

Closely spaced twin jet aircraft have been known to be susceptible to aft-end structural damage due to the high sound pressure levels resulting from twin jet screech. An initial engineering workstation tool to predict the occurence of screech, ultimately allowing the design of configurations which will not result in screech, is presented here. The model has been developed in a modular fashion to facilitate upgrades. The implementation takes advantage of a graphical interface, yielding predictions of screech amplitude versus frequency within a few seconds once the initial flowfield is defined. The four physically based modules in the code, for the instability waves, shock-vortex interaction, acoustic feedback and receptivity, are based on analytical, computational and experimental research. Preliminary results for 2-D jets illustrate the effects freestream Mach number and shear layer growth rate have on the screech amplitude and frequency. Author

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AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

N92-27906# McDonnell Aircraft Co., Saint Louis, MO.
ICAAS PILOTED SIMULATION EVALUATION
R. P. MEYER, R. J. LANDY, and D. J. HALSKI *In* AGARD, Air Vehicle Mission Control and Management 16 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

Described here are the Integrated Control and Avionics for Air Superiority (ICAAS) piloted simulation evaluations, along with the system development leading up to the simulations and the data analysis plan for evaluating simulation results. The ICAAS advanced development program is sponsored by the United States Air Force Wright Laboratory at Wright Patterson Air Force Base, Ohio. A research and development contract was awarded to the McDonnell Aircraft Company, St. Louis, Missouri, in September 1987. The program objective is to develop, integrate and demonstrate critical technologies which will enable United States Air Force tactical fighter 'blue' aircraft to kill and survive when outnumbered as much as four to one by enemy 'red' aircraft during air combat engagements. Primary emphasis is placed on beyond visual range (BVR) combat with provisions for effective transition to close-in combat. An overview is given of the ICAAS system and its functions. The hardware elements needed to implement the ICAAS system are described and require high throughput parallel processing Reduced Instruction Set Computer (RISC) computers and an advanced 'glass' cockpit. The development of the ICAAS system is discussed as it moved from rapid prototyping to unit testing of attack management and flight Management software and finally into hardware software integration testing prior to manned simulation. The Data Analysis plan for reducing piloted simulation results to assess system performance is described. The evaluation of the ICAAS system performance encompasses not only integrated system performance but also performance of individual ICAAS subsystems as they are reflected by measures of situation awareness, flight management utilization, weapon utilization and sensor effectiveness. This includes use of multiple measures of performance as well as univariate and multivariate analyses to assess ICAAS system performance. Author

N92-28093# Litton Industries, Blacksburg, VA. Poly-Scientific Div.
FIBER OPTIC DATA BUSSES FOR AIRCRAFT
NORRIS E. LEWIS *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 15 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A03/MF A02

A variety of fiber optic data busses are being developed for aircraft applications. This paper addresses five different data busses under consideration for both military and commercial aircraft. The impact of data bus protocol on component design, the effect of data bus topology on power budget and installation issues, and overall data bus performance are discussed. Author

N92-28376# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
APPLICATIONS OF ASICS TO AVIONICS
Feb. 1992 49 p
(AGARD-AG-329; ISBN-92-835-0657-X) Copyright Avail: CASI HC A03/MF A01

An overview of how Application Specific Integrated Circuits (ASICs) can be a key factor in avionics systems is presented. The technical capabilities and possibilities of ASICs in avionics applications are discussed along with the essential characteristics and various types of ASICs that are available. The computer aided design (CAD) tools necessary for the rapid development of ASICs are discussed. Two specific examples of applications are cited: (1) the imbedded computers necessary for airborne radar digital signal processing; and (2) the ASIC role in image processing for aircraft cockpits. For individual titles, see N92-28377 through N92-28380.

N92-28377# Thomson Composants, Saint Egreve (France).
WHAT IS AN ASIC?
J. M. BRICE and J. REDOLFI *In* AGARD, Applications of ASICs to Avionics 7 p (SEE N92-28376 19-06) Feb. 1992
(AGARD-AG-329) Copyright Avail: CASI HC A02/MF A01

Since the emergence of the first ASICs in 1975, many advances have occurred in this field. This has resulted in highly complex digital ASICs and very high speed analog circuits. This strong evolution did not really change the nature of the four ASIC families: full custom circuits, standard cells, programmable devices, and PLD's. Author

N92-28378# Thomson Composants, Saint Egreve (France).
THE SILICON COMPILER FOR DESIGNING MILITARY VLSI ASIC'S
J. M. BRICE *In* AGARD, Applications of ASICs to Avionics 14 p (SEE N92-28376 19-06) Feb. 1992
(AGARD-AG-329) Copyright Avail: CASI HC A03/MF A01

The capabilities of present day military electronics are a direct result of the use of the following two technologies: (1) very large scale integration (VLSI) and (2) silicon integrated circuits (ICs). As a result, defense electronics manufacturers are able to design increasingly sophisticated digital electronics systems. A discussion of complexity in digital Application Specific Integrated Circuits (ASICs) is presented. D.R.D.

N92-28379# Micro Circuit Engineering Ltd., Tewkesbury (England).
APPLICATIONS OF SILICON HYBRID MULTI-CHIP MODULES TO AVIONICS
E. S. ECCLES *In* AGARD, Applications of ASICs to Avionics 14 p (SEE N92-28376 19-06) Feb. 1992
(AGARD-AG-329) Copyright Avail: CASI HC A03/MF A01

Silicon-based multi-chip modules (MCMs) are an inevitable byproduct of reduced feature size and higher speed integrated circuit (IC) devices. Early versions are available and are being exploited in military and high performance commercial applications. Their use will proliferate rapidly over the next four years and is likely to extend the use of monolithic ICs into performance areas which were previously inaccessible. Author

N92-28380# Thomson-CSF, Montrouge (France). Direction Recherche et Technologie.
A RADAR SIGNAL PROCESSING ASIC AND A VME INTERFACE CIRCUIT
A. CHOCHOD *In* AGARD, Applications of ASICs to Avionics 6 p (SEE N92-28376 19-06) Feb. 1992
(AGARD-AG-329) Copyright Avail: CASI HC A02/MF A01

The purpose of this circuit is to perform real time signal processing for radar applications such as a missile seeker. There are two operating modes (standard and sample accumulation) and a variety of options through user selectable parameters and control logic (i.e. detection with global, local, or fixed threshold). Author

N92-32437# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
INTEGRATED TARGET ACQUISITION AND FIRE CONTROL SYSTEMS [SYSTEMES INTEGRES D'ACQUISITION D'OBJECTIFS ET DE CONDUITE DE TIR]
Feb. 1992 109 p In ENGLISH and FRENCH Symposium held in Ottawa, Canada, 7-10 Oct. 1991 Original contains color illustrations
(AGARD-CP-500; ISBN-92-835-0658-8) Copyright Avail: CASI HC A06/MF A02; 1 functional color page

The characterization of targets is of primary interest because it is needed for establishing the tactical situation, optimizing target acquisition, and optimizing armaments utilization. Due to the necessity of obtaining information on threats which have low signatures and are equipped with counter-measure systems, the operational specification of airborne systems have come to rely on the technologies providing multispectral analysis of targets. Specific topics discussed include aircraft fire control, air to air missiles, air to ground missiles, aerial warfare, multispectral detectors, integrated systems architectures and algorithms, and data fusion. For individual titles, see N92-32438 through N92-32450.

N92-32439# GEC Ferranti, Edinburgh (Scotland). Electro Optic Systems Group.
MULTISENSOR AIRBORNE TARGET ACQUISITION SYSTEMS AND THEIR INTEGRATION
J. W. JACK *In* AGARD, Integrated Target Acquisition and Fire Control Systems 6 p (SEE N92-32437 23-06) Feb. 1992 Sponsored by Ministry of Defence
(AGARD-CP-500) Copyright Avail: CASI HC A02/MF A02; 1 functional color page

Discussed here are the requirements for increased sensor performance. It is suggested that one solution may be to provide a dual sensor capability. The difficulties of conducting tests under realistic conditions are set out, and the alternative of providing calculated performance based on recorded weather and target data is suggested. Based on modeling for two locations in the Gulf region, it is shown that TV can offer major advantages in hot humid conditions. Equipment providing a dual sensor capability is described and the results of carrying out trials flying in the United Kingdom are presented. Author

N92-32447# Zeiss (Carl), Oberkochen (Germany).
AIRBORNE EXPERIMENTAL FLIR PROGRAM
KLAUS F. BOECKING *In* AGARD, Integrated Target Acquisition and Fire Control Systems 12 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A03/MF A02; 1 functional color page

The German Air Force has decided to build a forward looking infrared (FLIR) system in order to derive and to consolidate the different technical requirements for their different technical tasks. This FLIR design was designed and built on the basis of available and proven technologies. The equipment is pod-mounted in order to avoid modification of existing Tornado aircraft. Two different modes of operation are comprised in one hardware. These are the navigation mode, used as a pilot aid for flying at night and in adverse weather, and the fire control mode, used for passive targeting and navigation-update. The mechanical and optical designs are presented as well as the electronics architecture. The performance of the sensor system is described. Author

N92-32448# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Helicopter Div.
THE GERMAN ANTI TANK HELICOPTER PAH 2: AN EXAMPLE OF A FUTURE SENSOR PLATFORM
RUDOLF SCHRANNER, K. RUESKAMP, and HANS-DIETER VONBOEHM *In* AGARD, Integrated Target Acquisition and Fire Control Systems 4 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A01/MF A02; 1 functional color page

The German antitank helicopter PAH 2 is presently under full scale development, together with the French antitank helicopter HAP, in a cooperative effort between France and Germany. The PAH 2 represents the current state of the art in target acquisition and fire control systems for helicopters in Europe. The targeting system consists mainly of a mast mounted platform housing several

sensors operating in different spectral ranges. It is used for the detection, recognition, and identification of targets at increased ranges as well as to aim and guide 2nd and 3rd generation antitank missiles. Further sensors and systems are available to support the crew target acquisition or detection of threats in the battlefield and to support coordination of several helicopters in a flight. Author

N92-32449# Canadair Ltd., Montreal (Quebec). Surveillance Systems Div.
NAVAL TARGET CLASSIFICATION AND DESIGNATION WITH THE CL-227 SEA SENTINEL
HENRY J. SZOT and STEPHEN P. JONES (Paramax Electronic, Inc., Montreal, Quebec) *In* AGARD, Integrated Target Acquisition and Fire Control Systems 14 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A03/MF A02; 1 functional color page

The integration of the CL-227 Unmanned Air Vehicle (UAV) Sea Sentinel System with the Canadian Patrol Frigate (CPF) platform provides the naval target classification and designation capability that meets the mission requirements of this and the following decade. The developmental history and the operation of the system is described. Author

N92-32450# Wright Lab., Wright-Patterson AFB, OH.
AN INTEGRATED MULTIPLE-SENSOR FIRE CONTROL SYSTEM FOR AIR-TO-AIR COMBAT
ROBERT A. MANSKE and WILLIAM E. MOORE *In* AGARD, Integrated Target Acquisition and Fire Control Systems 12 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A03/MF A02; 1 functional color page

Described here is a system that includes integrated fire control algorithms, software, and related control and display concepts for air to air combat in the multiple target environment of the 1990's. This system, now completing advanced development, fuses data from multiple sensors and presents integrated fire control information to the pilot in a simplified manner for improved situation awareness and decreased workload. The resulting algorithms, software, and display concepts are described. The system was demonstrated and evaluated in a flight simulator with Air Force pilots. The fire control software, which was developed in the Ada language, was implemented in a distributed data processing complex using MIL-STD-1750A processors. The sensors and data links, as well as the aircraft and its environment, were simulated by mathematical models. Author

N93-19783# Sextant Avionique, Saint Medard en Jalles (France).
LIQUID CRYSTAL DISPLAYS REPLACING THE CRT AND CLE OF FUTURE COCKPITS [LES ECRANS A CRISTAUX LIQUIDES REMPLACANT DU CRT ET CLE DES FUTURS COCKPITS]
FREDERIC DELAUZUN *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 9 p (SEE N93-19757 06-54) Oct. 1992 In FRENCH
(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

Due to well-known advantages such as low weight, reduced volume, low consumption, visibility (under high brightness) reliability, to mention the most important, the flat panels have already started to replace the CRT in the world of military aircraft. Among flat panels, the liquid crystal active matrix display is the most advanced. Full colors and grey shades displays are mass produced for commercial applications and new military cockpits, both for airplanes and helicopters based on that technology (Rafale is used as an example to illustrate the advantages of LCD compared to CRT). Furthermore, liquid crystal panel is a technical key which will help future cockpit concepts to wake-up to life. The head level display and the large interactive display are among them. Projection techniques and liquid crystal cells are merged to take benefits of liquid crystal, removing the drawbacks (that notion is illustrated by a brief description of a head level display demonstrator). Author

N93-22028# Dornier-Werke G.m.b.H., Friedrichshafen (Germany).
THE AVIONIC SYSTEM OF THE EXPERIMENTAL STANDOFF DISPENSER ADW
JUERGEN SCHEUCH *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 6 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A02/MF A02

Last year, Dornier, a company of Deutsche Aerospace (DASA, Deutsche Aerospace AG) successfully completed flight tests with an experimental standoff dispenser, called ADW. ADW is the abbreviation of the German words for 'Standoff Dispenser Weapon' (ADW, Abstands Dispenser Waffe). The ADW test vehicle is an autonomous guided, non-powered missile with high navigation accuracy. It is used for in-flight ejection tests with different types of submunitions. It is equipped with an INS (Inertial Navigation System) updated by GPS (Global Positioning System) in order to guarantee a precise target approach. Author (revised)

N93-28871# Westinghouse Electric Corp., Baltimore, MD. Electro-Optical Systems Dept.
DESIGN CONSIDERATIONS FOR A NIGHT, AIR-TO-SURFACE ATTACK CAPABILITY ON A DUAL ROLE FIGHTER
ROBERT A. HALE, JOHN J. CHINO, L. LARKIN NIEMYER, JOHN R. JADIK, and BARRY E. LIGHTNER *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 8 p (SEE N93-28850 11-54) Apr. 1993 Prepared in cooperation with Westinghouse Electric Corp., Orlando, FL
(AGARD-CP-520) Copyright Avail: CASI HC A02/MF A03

The Falcon Knight design objective was to achieve a compact lightweight and affordable night air-to-surface attack capability for a small single seat dual role fighter. The design constraints were cost, performance, physical size, weight, aerodynamic impact, and ease of retrofit. An analysis of the mission and the pilot's tasks and workload during the mission revealed the need for two electro-optical lines-of-sight (LOS's). The first LOS, pilot age, is required to provide an uninterrupted night vision, or pilot age, capability for a high level of situational awareness at all normal pilot viewing angles. The second LOS, targeting, is to provide a simultaneous independent targeting capability for cueing, search, detection, recognition, fire control tracking, and/or weapon hand-off leading to the delivery of weapons on the target. The Falcon Knight forward looking infrared (FLIR) sensor is a unique optically multiplexed dual line of sight (LOS) Head Steered FLIR (HSF) which provides both pilot age and targeting LOS's simultaneously within the design constraints cited above. The Falcon Knight FLIR is also integrated with the aircraft's Fire Control Radar (FCR) to create an integrated FLIR/Fire Control Radar Multisensor. Westinghouse built a company funded Falcon Knight FLIR/Fire Control Multisensor Radar prototype. The prototype was evaluated in flight on the Westinghouse BAC 1-11 Avionics Test Bed aircraft. The United States Air Force is currently evaluating the Falcon Knight FLIR/Fire Control Radar Multisensor on the Advanced Fighter Technology Integration (AFTI) F-16 test aircraft at Edwards Air Force Base (AFB) California. Author (revised)

N94-29316# Aerospatiale, Toulouse (France).
HOW TO CONTROL THE INCREASE IN THE COMPLEXITY OF CIVIL AIRCRAFT ON-BOARD SYSTEMS
P. CHANET and V. CASSIGNEUL *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 10 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

After showing how the complexity of digital systems is doubling about every five years, and evoking the difficulties caused by this evolution, a methodological approach is described called the 'Systems Development Workshop' aiming to gain mastery of this evolution. Among design, production and validation stages, the importance of the design process is emphasized. The most acute problems of system development are generally described, and examples are given of the power and benefits that can be expected from computer design tools. System architecture design and functional specification are expanded somewhat, to show what benefits can be expected from an integrated approach. Through the SAO example, all development stages are evoked. A rough outline of the necessary capacities for a common work environment is drawn. Finally, it is noted that the increasing necessity of

international cooperation in civil aviation consolidates the proposed approach. Author

N94-29331# Wright Lab., Wright-Patterson AFB, OH.
A COMMON ADA RUN-TIME SYSTEM FOR AVIONICS SOFTWARE
CLIVE L. BENJAMIN, MARC J. PITARYS, ELIEZER N. SOLOMON, and STEVE SEDREL *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 11 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

The United States Air Force (USAF) requires the use of the Ada programming language in the development of new weapon system software. Each Ada compilation system uses a Run-Time System (RTS) for executive services such as tasking, memory management, and system initialization. Implementing and using custom RTS services in each software development activity inhibits avionics software reuse and portability. In addition, the USAF must support many Ada compilers over the operational life of the weapon system. Finally, extensive testing and knowledge is required for each RTS. In 1990 the USAF began defining a Common Ada Run-Time System (CARTS) for real-time avionics applications. A contract was awarded to Westinghouse Electric Corporation (WEC) with subcontracts issued to compiler vendors DDC-I, Inc. and Tartan, Inc. A specification for the CARTS was completed in 1991 and coding of selected CARTS features was undertaken. The specification defined common interfaces between the application software and the RTS, and between the Ada compiler and the RTS. Incremental coding of the CARTS prototype is being done by DDC-I for the MIPS R3000 processor, and by Tartan for the Intel 80960 MC processor. Several prototypes have been developed and tested. This paper covers the significant CARTS features and services offered to avionics software engineers. The paper provides the results of performance testing of the CARTS features. Finally, this paper provides information on the appropriate use of the CARTS by avionics software engineers.
Derived from text

N94-29332# Alsys, Inc., Saint Cloud (France).
ADA RUN TIME SYSTEM CERTIFICATION FOR AVIONICS APPLICATIONS
JACQUES BRYGIER and MARC RICHARD-FOY *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 9 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The certification procedures apply to a fully developed system including both hardware and software components. The issue is that the equipment supplier must integrate various components coming from separate sources. In particular, the Ada Run Time System is embedded in the equipment like any other application component. This leads to two major requirements: the Ada Run Time System must be a glass box, and unused run-time services must be eliminated from the embedded components. The first requirement comes from the civil aviation procedures DO 178A, and the second is a consequence of the need to proof the system. This can lead to the elimination of some unpredictable or unsafe Ada language features. The criticality of the system consists of three levels: critical, essential, and non-essential. The report ARINC 613 (from the Airlines Electronic Engineering Committee) surveys the Ada language and provides a list of features not to be used in avionics embedded software, at least for the first two levels.
Author (revised)

N94-29334# Alenia, Turin (Italy).
ON GROUND SYSTEM INTEGRATION AND TESTING: A MODERN APPROACH
B. DIGIANDOMENICO *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 7 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

Modern aircraft, military or civil, incorporate the most up-to-date technology from all fields of research and development. There is an increasing tendency to develop digital control systems to replace analog control systems in all areas: engine control, power generation, fuel control, and environmental control. Digital systems are felt to be irreplaceable in avionics, and they are quickly approaching this level in flight control systems. Indeed, digital systems are responsible for the increased sophistication of modern aircraft and for the success of avionics as it now exists. The net result is that, while in the first generation of jet planes there were no onboard computers, modern aircraft may have more than twenty--with single or multiple 32 bit microprocessors, multiple megabytes of RAM, and sophisticated real time operating systems. Author (revised)

N94-29336# Wright Lab., Wright-Patterson AFB, OH. Avionics Logistics Branch.
VALIDATION AND TEST OF COMPLEX WEAPON SYSTEMS
MARK M. STEPHENSON *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 12 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

As avionics software complexity increases, traditional techniques for avionics software validation and testing become time consuming, expensive, and ultimately unworkable. New test issues arise with the development and maintenance of complex 'super federated' systems like that of the B-2 and highly integrated systems like that of the F-22. Upgrades to existing weapon systems that produce a blend of federated and integrated architectures further complicate the problem. This paper discusses the limitations of current approaches, equipment, and software. It defines a next generation of avionics software validation and test procedures, along with the hardware and software components that are required to make the process work. The central goals of the process and components are to reduce development and maintenance costs, to minimize womanpower requirements, to decrease the time required to perform the testing, and to insure the quality of the final product. The process is composed of unit test, component test, configuration item test, subsystem test, integration test, avionics-system test, and weapon-system test. Some of the topics covered are as follows: automated testing of avionics software, real-time monitoring of avionics equipment, nonreal-time and real-time avionics emulation, and real-time simulation. This paper is based upon several years of experience in the following areas: (1) research and development of new technologies to improve the supportability of weapon-system software; and (2) design and implementation of facilities for the development, enhancement, and test of avionics software. Author (revised)

N94-29348# International Business Machines Corp., Owego, NY.
DSSA-ADAGE: AN ENVIRONMENT FOR ARCHITECTURE-BASED AVIONICS DEVELOPMENT
LOUIS H. COGLIANESE and RAYMOND SZYMANSKI *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 8 p (SEE N94-29315 08-61) Nov. 1993 Sponsored in part by DARPA
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

This paper describes the domain-specific software architectures avionics development application generation environment (DSSA-ADAGE) under development for the United States' Defense Advanced Research Projects Agency (DARPA) and the USAF's Wright Laboratory. It introduces the goals of the project, recent results in the development of a reusable software architecture for integrated avionics, a description of the process used to develop the architecture, and an overview of the ADAGE development environment. The remainder of the paper is devoted to presenting the formal languages that describe the problem, solution, and implementation views of the avionics architecture.
Derived from text

N95-20631# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
ADVANCED PACKAGING CONCEPTS FOR DIGITAL AVIONICS [LES TECHNIQUES AVANCEES DE MISE SOUS BOITIER]
Oct. 1994 287 p In ENGLISH and FRENCH Symposium held in San Diego, CA, 6-9 Jun. 1994
(AGARD-CP-562; ISBN-92-836-0004-5) Copyright Avail: CASI HC A13/MF A03

A critical impediment to significantly improving the performance of digital airborne electronics or avionics is the limitation posed by current electronics packaging concepts. This symposium brought together experts from seemingly diverse, but interlocking disciplines ranging from logisticians to digital designers to mechanical engineers to establish the current baseline in digital packaging, failure modes of the electronics and support problems. Trends in

both supportability and processing were described for early 21st century application. Along with the projections of asymptotic increase in signal, image and data processing, dramatic increases in thermal densities, chip interconnects, correctors and backplane traffic were described. For individual titles, see N95-20632 through N95-20659.

N95-20632# Wright Lab., Wright-Patterson AFB, OH. Avionics Directorate.

THE IMPACT OF ADVANCED PACKAGING TECHNOLOGY ON MODULAR AVIONICS ARCHITECTURES

REED MORGAN and JOHN OSTGAARD *In* AGARD, Advanced Packaging Concepts for Digital Avionics 12 p (SEE N95-20631 06-06) Oct. 1994

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

This paper explores how advances in digital packaging will impact network requirements at the system level. Two main issues connected with modular digital packaging for avionics were investigated: (1) Can conventional electrical designs continue to handle the information network speed and wirability requirements needed at the backplane to efficiently utilize advanced modular data and signal processors? (2) Considering projected network requirements for future sensors, displays, etc., (which are made possible because of digital packaging advances), what type of system architecture will be needed? The paper concludes that: (1) Beyond the module (PCB) interface, a new type of backplane implementation will eventually be needed to support the flexibility and growth needs of modular processing. Several new approaches other than a passive electrical backplane could be employed; however, a switched, photonic-based approach is proposed for information distribution between digital processing modules as well as for interconnection between peripherals. Digital packaging advances will result in I/O speeds of about 2 Gigabits/sec, and (2) advanced integrated RF and EO sensors and display technologies will require network data rates in the range of 2 Gigabits/sec in order to communicate in real time with the high speed signal and graphics processor modules in the common integrated processor racks. Many of these 'peripheral' functions will require virtual point-point links because continuous, streaming data in involved. This resulting system architecture recommended is a switched optical network which interconnects sources and sinks of information to the modular processing assets, as well as providing a network for intermodule intercommunication within the rack. Issues of protocol control of this network remain. Further, several advances in photonic packaging and connectors will be required to make this new architectural approach a reality. Although photonics offers the best long-range solution, significant technology difficulties must be overcome. Author

N95-20633# Naval Air Warfare Center, Indianapolis, IN. Aircraft Div.

STANDARD HARDWARE ACQUISITION AND RELIABILITY PROGRAM (SHARP) ADVANCED SEM-E PACKAGING

MARY H. MOSIER and ANTHONY HAWKINS *In* AGARD, Advanced Packaging Concepts for Digital Avionics 10 p (SEE N95-20631 06-06) Oct. 1994

(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

The objective of the 'Advanced SEM-E Packaging' is 'to identify existing SEM-E and modular avionics characteristics; delineate where they are not defined; and document consensual requirements and guidance for military and commercial applications to provide a framework for open systems architecture implementation'. SHARP has teamed with the Air Force Modular Avionics Systems Architecture (MASA) Program to bridge Industry and government agencies in defining and documenting Standard Electronic Module (SEM) format E advanced packaging requirements. The baseline for the working group has been identified, but SHARP and MASA are soliciting participation and input from industry, other agencies, and NATO. Author

N95-20634# Dassault Aviation, Saint-Cloud (France).

FASTPACK: OPTIMIZED SOLUTIONS FOR MODULAR AVIONICS DERIVED FROM A PARAMETRIC STUDY. PART 1: PLATFORM FEATURES [FASTPACK: SOLUTIONS OPTIMISEES POUR LE CONDITIONNEMENT DE L'AVIONIQUE MODULAIRE ISSUES D'UNE ETUDE PARAMETRIQUE. PART 1: ASPECTS PORTEUR]

G. VEBER, S. BARBAGELETA (Eurocopter France, Marignane, France.), and P. HELIE *In* AGARD, Advanced Packaging Concepts for Digital Avionics 11 p (SEE N95-20631 06-06) Oct. 1994 In FRENCH

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

Modular avionics is one of the major concepts to be applied to future avionics systems with the objective of cost (LCC - Life Cycle Cost) containment and improvement of operational performance. The objectives associated with such a concept are numerous: improvement of reliability, standardization, interchangeability, interoperability, etc. To obtain these objectives it is necessary to define characteristics standards for modules (LRM - Line Replaceable Module). The definition of these standards for LRM has a direct impact on the modules and their integration. The choice of the best concept takes place through a careful study of the repercussions of each solution on all levels (racks, bays and platforms), in all the technical fields (thermal, electric, mechanical, electromagnetic protection, connectors). This article presents the results of a parametric platform/system-avionics study and more particularly the possible choices for orientation of the platform on aircraft or helicopters. The method used defines the platform constraints to be parameterized and their interactions. The effects are initially integrated in a model representative of standard missions. Thus the results, field by field, show the importance of the effects of constraints on the platform system. Finally, a process of complete dimensioning of the platform, including the functional reliability aspects leads to the synthesis. This allows both a quantitative and qualitative check of the robustness of the compromises carried out. In conclusion, the control of the platform/avionics-system compromise, by an approach of simultaneous engineering, makes it possible to justify a solution of conditioning of the modular avionics in the optics of a future system. Transl. by CASI

N95-20635# Thomson-CSF, Paris (France).

FASTPACK: OPTIMIZED SOLUTIONS FOR MODULAR AVIONICS DERIVED FROM A PARAMETRIC STUDY. PART 2: AVIONICS

M. CAPLOT, G. LABAUNE, C. CAPOGNA, C. SARNO (Sextant Avionique, Valence, France.), J. HERREWYN (Dassault Electronique, Saint-Cloud, France.), J. C. DHAUSSY (Dassault Electronique, Saint-Cloud, France.), and P. BLEICHER (Dassault Electronique, Saint-Cloud, France.) *In* AGARD, Advanced Packaging Concepts for Digital Avionics 13 p (SEE N95-20631 06-06) Oct. 1994 Sponsored by Ministry of Defence

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

The main requirements for modular avionics have a strong influence on the Packaging solutions for the Line Replaceable Modules (LRM's) and the rack. Packaging is here including: mechanical concepts, cooling, power supplies, interconnections and electromagnetic compatibility. To define the packaging solutions for the next generation of avionics, a parametric study, FASTPACK, has been performed at the platform and avionics levels. The present paper deals with the avionics part and shows how the FASTPACK parametric study has been conducted in order to define a synthesis in each domain, used to derive Packaging concepts. The main results include the choice of a LRM format, called FAST, a distributed power supply network within the rack, conduction and liquid flow through cooling, shielding on the rack against external electromagnetic threats and shielding on the LRM for rack internal interferences and, finally, the first definition of the LRM connector. Author

N95-20636# Naval Air Warfare Center, Warminster, PA. Aircraft Div.

THE ADVANCED AVIONICS SUBSYSTEM TECHNOLOGY DEMONSTRATION PROGRAM

TIM MONAGHAN, GHANI KANAWATI, JACOB ABRAHAM, DANIEL OLSON, and RAVI IYER *In* AGARD, Advanced Packaging Concepts for Digital Avionics 13 p (SEE N95-20631 06-06) Oct. 1994

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

The Navy's Advanced Avionics Subsystem Technology (AAST) Fault Tolerant program is clarifying the Navy's fault tolerant avionics specifications methods and acceptance tests. The goal of the program will be to clarify the Specification and Statement of Work language needed in future procurements and to demonstrate fault tolerant validation tools on the avionics design. A set of tool features will then be developed that spans the needs of fault tolerant computer system design from early concept studies to full scale production and operational support, both hardware and software. The paper will give an overview of the AAST Fault Tolerant Demonstration and focus on two tools that are being used in the demonstration: FERRARI - a software fault injector that will be used to validate the fault tolerance of the Common Integrated Processor (CIP), the F-22 Mission Processor, and GRIND - a concept evaluation tool that will be used to evaluate the overall CIP architecture. Author

N95-20641# GEC-Marconi Research Centre, Great Baddow (England).

MCMS FOR AVIONICS: TECHNOLOGY SELECTION AND INTERMODULE INTERCONNECTION

N. CHANDLER, I. R. CROSTON, S. G. TYLER, T. G. HAMILL (GEC-Marconi Avionics Ltd., Rochester, England.), and P. E. HOLBOURN (GEC-Marconi Avionics Ltd., Edinburgh, Scotland.) *In* AGARD, Advanced Packaging Concepts for Digital Avionics 15 p (SEE N95-20631 06-06) Oct. 1994 Sponsored by European Commission

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

There are already several Multi Chip Module (MCM) technologies suitable for avionics applications, and new variations and updates are continually being added. The optimum technology choice for each avionics application will depend on many factors, including the electrical and thermal requirements, the operating environment, size, weight, quantity, cost, etc. This paper will compare the attributes of the various MCM technologies, both at present and future trends, including 3D assembly/packaging and the use of active substrates for MCM-D's. The means of mounting MCM's and interconnecting them into the system using electrical or optical interconnection will also be compared. Some of the methods used to remove very high levels of power dissipation will also be discussed, in relation to the different technologies. The requirements of electronic modules in different parts of avionics systems may be sufficiently different that alternative solutions are optimal for the various parts. The paper will briefly review the range of requirements across military (and comparable civil) avionics systems and, by considering the technology options, indicate how the optimum choice can be decided, both for the MCM's themselves and for the means of interconnection between MCM's and from MCM's to other parts of the system. Author

N95-20650# Naval Air Warfare Center, Warminster, PA. Aircraft Div.

THE IEEE SCALABLE COHERENT INTERFACE: AN APPROACH FOR A UNIFIED AVIONICS NETWORK

RALPH LACHENMAIER and THOMAS STRETCH (AMPAC, Inc., Norristown, PA.) *In* AGARD, Advanced Packaging Concepts for Digital Avionics 10 p (SEE N95-20631 06-06) Oct. 1994

(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

The U.S. Navy Next Generation Computer Resources (NGCR) High Speed Data Transfer Network (HSDTN) program has chosen the IEEE Scalable Coherent Interface (SCI) as one of its baseline standards. This paper proposes to use SCI as a unified avionics network and describes SCI and extensions to it -- particularly an extension known as SCI/ Real Time (SCI/RT). Because SCI can be used in a serial configuration, such a network provides an alternative to the need for ever denser and ever more reliable backplane connectors by reducing the number and size of interconnects and, hence, the need for large numbers of pins. In addition, SCI reduces packaging problems by using a small amount of board real estate and by using distance insensitive links which can extend board to board or box to box, thus facilitating a distributed backplane approach for retrofit aircraft applications. SCI is currently being applied to both parallel and to serial implementations, to both message passing and shared memory computing paradigms, and to both electrical and optical physical layers. SCI/RT is a set of proposed enhancements, developed initially by the Canadian Navy and now being evaluated by the NGGR HSDTN and IEEE working groups, to make SCI more fault tolerant and to provide the determinism and priorities necessary to support Rate Monotonic Scheduling. Addition of these features will allow SCI to perform in a unified and seamless manner, the functions of command and control interconnect, data flow network and sensor/video network. Electrical and optical, and serial and parallel links can be intermixed for the most cost effective solution. As an added benefit, SCI has potential for use interconnecting multiple processing chips on the same board. Author

N95-20657# Thomson-CSF, Paris (France). Div. Radars et Contre-Mesures.

MODULAR SUPPLIES FOR A DISTRIBUTED ARCHITECTURE [ALIMENTATIONS MODULAIRES POUR UNE ARCHITECTURE DISTRIBUEE]

A. MOREAU, J. M. REY, M. CAPLOT, and J. P. DELVINQUIER *In* AGARD, Advanced Packaging Concepts for Digital Avionics 12 p (SEE N95-20631 06-06) Oct. 1994 In FRENCH

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

Future avionics systems will be based on a modular architecture in which each elementary function will correspond to a line replacable module (LRM). Parametric studies, such as FASTPACK, showed that the optimal solution for the supply systems was an architecture distributed on only one level of energy transformation, i.e., a modular supply on each LRM able to deliver 50 W with 100 W directly starting from the main supply system (270 V(dc) or three-phase network 200 V/400 rectified Hz). In order to obtain a coherent level of integration of the digital circuits, it was necessary to develop such modular supplies with a power density of about 1500 W/dm(sup 3) per unit of volume. In addition, so that these supplies can be established directly on a LRM simple face, their thickness had to be limited to 6.8 mm (case included/understood). To achieve this goal, a total integration that guaranteed the performances of the electric supplies, high frequency hybrid converters (of the order of MHz) were developed. After a presentation of the advantages of an architecture of distributed supply and a review of the main technical aims, this article describes the techniques and technologies implemented to achieve these goals. A thorough description of the developed modular supplies is given for delivered powers ranging between 50 W and 100 W and for various output voltages. Finally, the future developments planned to reach a power density of 4000 W/dm(sup 3) per unit of volume are reviewed. Transl. by CASI

N95-20659# Rohde and Schwartz, Munich (Germany).

MODULAR CNI AVIONICS SYSTEM

P. H. REITBERGER and G. MEY (Ministry of Defence, Bonn, Germany.) *In* AGARD, Advanced Packaging Concepts for Digital Avionics 11 p (SEE N95-20631 06-06) Oct. 1994

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

Today's aircraft contain a multitude of different radio functions for communications, navigation and identification. The individual radio functions, like VHF/UHF, JTIDS/ MIDS, GPS or NIS, are each handled by an individual piece of equipment consisting of several LRU. In the absence of built-in redundancy, the failure of a single LRU can result in a failure of a radio function. In the future, individual radio functions need to be integrated in a modular system concept, the modular CNI system (communication - navigation - identification). Author

07

AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and onboard auxiliary power plants for aircraft.

N92-27461# Textron Lycoming, Stratford, CT.
APPLICATION OF CFD IN THE DESIGN OF GAS TURBINE ENGINE COMPONENTS
ARUN K. SEHRA, MOHAMED A. ABOLFADL, and MOHAMED G. ZEDAN *In* AGARD, CFD Techniques for Propulsion Applications 26 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
The application is illustrated of three dimensional viscous procedures for optimizing the turbomachinery component geometry. Specific cases presented include the application of 3-D viscous analyses to a transonic axial compressor rotor, a splittered axial compressor rotor, a turbine rotor, and an exhaust mixer nozzle. Application of an axisymmetric Navier-Stokes solver to the inlet particle separator, and a two dimensional inverse design procedure for customizing compressor airfoil geometry are also briefly included. Author

N92-27462# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
VALIDATION OF A CANARI CODE BY THE COMPUTATION OF THREE DIMENSIONAL TURBULENT FLOW IN TURBINE VALVE [VALIDATION DU CODE CANARI PAR LE CALCUL DE L'ECOULEMENT TRIDIMENSIONNEL TURBULENT DANS UN DISTRIBUTEUR DE TURBINE]
BEATRICE ESCANDE and LAURENT CAMBIER *In* AGARD, CFD Techniques for Propulsion Applications 8 p (SEE N92-27450 18-34) Feb. 1992 In FRENCH; ENGLISH summary
(AGARD-CP-510) Copyright Avail: CASI HC A02/MF A06
The preliminary results are presented which were obtained in order to validate the CANARI code in a turbomachinery case. This code solves the Reynolds averaged compressible three dimensional Navier-Stokes equations. It is applied to the flow computation through a high pressure turbine annular cascade. This computation is characterized by the use of a highly stretched O mesh around the blades and of H meshes for the upstream and downstream regions, in order to allow an accurate description of the leading edge and trailing edge phenomena. The configuration studied is an experimental set-up which has been recently realized at ONERA for the validation of computational codes. Author

N92-27463# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).
COMPUTATION AND VISUALIZATION OF SPECIFIC FLOW PHENOMENA IN TURBOMACHINERY APPLICATION
J. HAARMEYER and B. STUBERT *In* AGARD, CFD Techniques for Propulsion Applications 8 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A02/MF A06
Capacity and speeds in industrial computer hardware allows the complete numerical evaluation of the three dimensional flow field through turbomachinery blading. Detailed consideration of specific flow phenomena like horseshoe vortex or tip clearance effects is of increasing importance in the engine design process. The large amount of data produced by a 3-D calculation requires separate development of algorithms for visualization of the computational results. Numerical techniques for the integration of both streamlines and vortex lines through 3-D vector fields are needed to identify fluid flow features based on values at discrete grid points. Such an integrated technique is covered and also includes a search algorithm for places of local rotations. Some evaluations of Euler calculations in a turbomachinery application are shown. Author

N92-27464# Vrije Univ., Brussels (Belgium). Computational Fluid Dynamics Group.
AN INTEGRATED CFD SYSTEM FOR 3D TURBOMACHINERY APPLICATIONS
C. HIRSCH, C. LACOR, C. DENER, and D. VUCINIC *In* AGARD, CFD Techniques for Propulsion Applications 15 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
A complete CFD system, composed of an interactive mesh generator, an efficient flow solver and an advanced, portable, flow visualization system is presented for turbomachinery applications. The mesh generator (IGG) and the visualization system (CFView) have the same user interface and call on Object Oriented Programming on top of X Windows. The flow solver is developed within a multigrid method, where the time integration schemes are considered as 'smoothers'. Both explicit or implicit time integration methods can be chosen. The explicit integration is based on the Runge-Kutta method and the implicit solver uses relaxation methods with Gauss-Seidel point or line strategies. The space discretization allows for central as well as upwind schemes and algebraic or two equation turbulence models are available. The application to an annular turbine blade row is shown. Author

N92-27466# Royal Aerospace Establishment, Farnborough (England).
PREDICTIONS AND MEASUREMENTS OF 3D VISCOUS FLOW IN A TRANSONIC TURBINE NOZZLE GUIDE VANE ROW
G. C. HORTON, S. P. HARASGAMA, and K. S. CHANA *In* AGARD, CFD Techniques for Propulsion Applications 16 p (SEE N92-27450 18-34) Feb. 1992 Previously announced as N92-14319
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
A transonic turbine nozzle guide vane was tested in an annular cascade with two different endwall geometries. The measurements were taken at engine representative flow conditions and include surface static pressures and a downstream area traverse of total pressure. The flow through these geometries was modeled at the test conditions using a three dimensional viscous flow program. The effects of different mesh densities and two turbulence models were studied. Predictions of secondary flow and loss were obtained and are compared with the experimental measurements. The different turbulence models were found to have little effect in the predicted overall loss though there were differences in the distribution and the shape of the vane wakes. The one equation turbulence model produced wakes which had similar levels of total pressure deficit to the experiment and had a more similar shape than those with the Baldwin-Lomax algebraic model. Author

N92-27469# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
STEADY AND UNSTEADY 3D FLOW COMPUTATION THROUGH A TRANSONIC TURBINE STAGE [CALCULS 3D STATIONNAIRE ET INSTATIONNAIRE DANS UN ETAGE DE TURBINE TRANSSONIQUE]
ALAIN LEMEUR *In* AGARD, CFD Techniques for Propulsion Applications 24 p (SEE N92-27450 18-34) Feb. 1992 In FRENCH; ENGLISH summary
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
The following problems are discussed. The best approach in order to obtain the average characteristics of the flow field by directly using a three dimensional computation on a complete turbomachinery stage. The real flow is absolutely 3-D and unsteady. This implies that numerical simulation of the flow must be unsteady. Therefore, it is necessary to make more or less rigorous unsteady computation or averaged steady computation can be directly performed. Two different ways to carry out computation on a highly loaded turbine stage are given and analyzed. The steady approach in which the average flow is redistributed at each iteration between both rows, in order to obtain the average steady solution. And the unsteady approach by taking into account several channels on both rows. The computation is purely unsteady with a time periodicity; i.e., if a result is obtained at time t, the same results must be found at time t + T, T being the time period. In these cases, a time average must be made over a period in order to obtain the 3-D flow field average. Author

N92-27484# Rolls-Royce Ltd., Bristol (England). Combustion Technology Dept.

MODELLING THE VAPORISER AND PRIMARY ZONE FLOWS FOR A MODERN GAS TURBINE COMBUSTION CHAMBER

N. R. BOND, J. M. LEVALLOIS, and K. R. MENZIES *In* AGARD, CFD Techniques for Propulsion Applications 18 p (SEE N92-27450 18-34) Feb. 1992

(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06

A three dimensional curvilinear finite volume computational fluid dynamics (CFD) code has been applied to aid understanding of the mechanisms leading to observed baseline temperature patterns on a modern vaporizer combustion chamber. This code calculates recirculating, turbulent, combusting flows with a k-epsilon turbulence model and a conserved scalar/local chemical equilibrium combustion model. Predictions were obtained for both the vaporizer internal flows and for the complete flametube; the latter used the predicted vaporizer exit flow patterns as boundary conditions. The vaporizer flow models displayed a sensitivity to the fuel injector location which was subsequently confirmed by water analogy experiments. In conjunction with the flametube calculations, the effect of injector geometry and location on the primary zone flow patterns and temperatures were assessed, explaining the experimental results. The computational studies suggested a modified fuel injector geometry to reduce sensitivity and improve fuel distribution, which was validated by subsequent experiments in the full combustor. Author

N92-28458# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

STEADY AND TRANSIENT PERFORMANCE PREDICTION OF GAS TURBINE ENGINES [PREDICTION DES PERFORMANCES DES MOTEURS A TURBINE A GAZ EN REGIMES ETABLI ET TRANSITOIRE]

May 1992 189 p Lectures held in Cambridge, MA, 27-28 May 1992, in Neubiberg, Fed. Republic of Germany, 9-10 Jun. 1992, and in Chatillon/Bagneux, France, 11-12 Jun. 1992

(AGARD-LS-183; ISBN-92-835-0674-X; AD-A253824) Copyright Avail: CASI HC A09/MF A02

Aero-thermodynamic performance prediction methods for gas turbine engines with respect to steady and transient operation are discussed. This includes advanced cycle calculation methods, also taking into account variable cycle engine types. A very important objective is the consideration of installation effects, i.e., Reynolds number and inlet distortions, as well as advanced control concepts for increasing engine surge margins. In addition to these topics, individual papers include practical considerations in designing the engine cycle, dynamic simulation, inlet distortion effects in aircraft propulsion system integration, 'smart' engines, and performance and health monitoring models. For individual titles, see N92-28459 through N92-28467.

N92-28459# Carleton Univ., Ottawa (Ontario). Dept. of Mechanical and Aerospace Engineering.

OVERVIEW ON BASIS AND USE OF PERFORMANCE PREDICTION METHODS

H. I. H. SARAVANAMUTTOO *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 18 p (SEE N92-28458 19-07) May 1992

(AGARD-LS-183) Copyright Avail: CASI HC A03/MF A02

The basic methods of component matching, which is central to the prediction of gas turbine performance, are outlined. Steady-state prediction of off-design performance must be done at the beginning of an engine development program. This ensures that the engine can satisfy all the mission requirements. The matching techniques can be extended to predict transient performance, which is essential for controls development and to ensure good engine handling. The large amount of computation required demands the use of computer modelling and the role of modelling in the development program and the basic requirements for performance modelling are described. Author

N92-28460# Royal Aerospace Establishment, Farnborough (England). Air Vehicle Performance Dept.

PRACTICAL CONSIDERATIONS IN DESIGNING THE ENGINE CYCLE

M. G. PHILPOT *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 24 p (SEE N92-28458 19-07) May 1992 Sponsored by Ministry of Defence

(AGARD-LS-183) Copyright Avail: CASI HC A03/MF A02

To define the cycle parameters and calculate the performance of a real engine, numerous practical constraints need to be taken into account. These fall into two main categories: the limitations of available component technologies; and the operational considerations that are dependent on aircraft application. The main technology limiters are discussed. How they are incorporated into the cycle definition process is indicated. Operational factors include the extent of the intended flight envelope and the range of the critical flight conditions for which performance must be assured, and the balance to be struck between minimizing fuel consumption, maximizing installed power, and constraining costs of ownership. Taking these technology and operational influences into account, the basic cycle characteristics and approach to cycle choice are examined for three main classes of aircraft: subsonic transports, military combat aircraft, and helicopters. Author

N92-28461# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Engineering Div.

STEADY AND TRANSIENT PERFORMANCE CALCULATION METHOD FOR PREDICTION, ANALYSIS, AND IDENTIFICATION

JEAN PIERRE DUPONCHEL, JEAN LOISY, and RENE CARRILLO *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 21 p (SEE N92-28458 19-07) May 1992

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The detailed design and development of turbofans involves the prediction and identification, by means of test analysis, of the performance of the engine and its components. The thermodynamic simulation and analysis codes integrate existing knowledge and interpretations of the detailed operating procedure of the components of the engine being developed. The relevance of the predicted performance depends on the quality of the representation of the various physical phenomena affecting the characteristics of the components and, consequently, on the incorporation of experimental correlation in the modelling. In this context, the representation of compressor and turbine characteristics is particularly important. We will analyze the ability of corrected parameters to represent MACH similitude at the component inlet under various conditions. Author

N92-28462# Carleton Univ., Ottawa (Ontario). Dept. of Mechanical and Aerospace Engineering.

COMPONENT PERFORMANCE REQUIREMENTS

H. I. H. SARAVANAMUTTOO *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 10 p (SEE N92-28458 19-07) May 1992

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Component data are essential for modelling the overall performance of gas turbines. The component characteristics are not easily obtained, and much of the data are proprietary and not available in the open literature. Several methods are available for estimating component characteristics and are briefly described. The requirements of users and manufacturers are quite different, but both can produce fully credible performance models. Author

N92-28463# Virginia Polytechnic Inst. and State Univ., Blacksburg, VA. Dept. of Mechanical Engineering.

DYNAMIC SIMULATION OF COMPRESSOR AND GAS TURBINE PERFORMANCE

WALTER F. OBRIEN *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 28 p (SEE N92-28458 19-07) May 1992

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Dynamic performance simulation models are discussed with emphasis on the fundamental principles of the models and the methods used to represent component and stage flow characteristics. Results of several simulations of the dynamic behavior of multistage compressors are shown with comparisons to experimental data. Possibilities for advanced computational

techniques for near-real-time simulations of compressors and gas turbines are reviewed. Author

N92-28464*# Cambridge Univ., Cambridge (England).
INLET DISTORTION EFFECTS IN AIRCRAFT PROPULSION SYSTEM INTEGRATION
J. P. LONGLEY (Cambridge Univ. (England).) and E. M. GREITZER (Massachusetts Inst. of Tech., Cambridge.) *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 18 p (SEE N92-28458 19-07) May 1992 Sponsored by NASA. Lewis Research Center; GE; and Rolls-Royce Ltd.
(AGARD-LS-183) Copyright Avail: CASI HC A03/MF A02
A tutorial survey of inlet flow distortion effects on engine performance and stability is presented. Inlet distortions in aero engines arise through a variety of causes. They can be essentially steady, due to non-axisymmetric intake duct geometry, or time varying, for example from flow separation off the lip of the inlet during maneuvers or shock-induced separation during supersonic flight. Whatever the cause, the result is generally a decrease in performance and, more importantly, a lessening of the stable flow range of the compressor. The distortions are generally three-dimensional. It is an extremely useful simplification to break them, at least conceptually, into radial and circumferential non-uniformities and approach each separately. Purely radial distortions can be treated by the methods that were developed for designing compressors in nominally axisymmetric inlet flow, and this type of distortion will be only briefly discussed. Circumferential non-uniformities, however, introduce additional fluid dynamic features into the analysis of compressor behavior and often have the larger impact on performance and stability. Thus we concentrate mainly on the effects of steady circumferential inlet flow distortion. Author

N92-28465# Technische Univ., Munich (Germany). Performance Dept.
CALCULATION OF INSTALLATION EFFECTS WITHIN PERFORMANCE COMPUTER PROGRAMS
J. KURZKE *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 19 p (SEE N92-28458 19-07) May 1992
(AGARD-LS-183) Copyright Avail: CASI HC A03/MF A02
Gas turbine engine components, such as compressors, burners, and turbines are usually tested on rigs prior to installation into an engine. In the engine, the component behavior is different for a variety of reasons. The installation effects are caused by small geometrical differences due to nonrepresentative rig operating temperatures and pressures, by different gas properties and Reynolds numbers and by radial as well as circumferential temperature and pressure profiles at the inlet to the component. For highly accurate performance predictions these rig-to-engine effects are taken into account. Traditionally the term 'installation' is also used for describing all the differences in engine operation and behavior between testbed and aircraft. Intake and afterbody drag, power offtake and bleed, as well as intake pressure losses and inlet flow distortion have significant impact on airflow, thrust, specific fuel consumption, and compressor stability. Using modern performance synthesis programs all these effects can be simulated. Author

N92-28466*# Massachusetts Inst. of Tech., Cambridge, MA. Gas Turbine Lab.
DYNAMIC CONTROL OF AERODYNAMIC INSTABILITIES IN GAS TURBINE ENGINES
E. M. GREITZER, A. H. EPSTEIN, G. R. GUENETTE, D. L. GYSLING, J. HAYNES, G. J. HENDRICKS, J. PADUANO, J. S. SIMON, and L. VALAVANI *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 20 p (SEE N92-28458 19-07) May 1992 Sponsored by NASA. Lewis Research Center; AFOSR; ONR; Pratt and Whitney Aircraft; and Army Aviation Systems Command
(AGARD-LS-183) Copyright Avail: CASI HC A03/MF A02
This lecture discusses the use of closed loop control at the component level to enhance the performance of gas turbine engines. The general theme is the suppression of flow instabilities (rotating stall and surge) through use of feedback, either actively or by means of the aeromechanical coupling provided by tailored structures. The basic concepts that underlie active control of turbomachinery instability, and their experimental demonstration, are first described for a centrifugal compressor. It is shown that the mechanism for stabilization is associated with damping of unsteady perturbations in the compression system, and the steady-state performance can thus remain virtually unaltered. Control of instability using a tailored structure is then discussed, along with experimental results illustrating the flow range extension achievable using this technique. A considerably more complex problem is presented by active control or rotating stall where the multi-dimensional features mean that distributed sensing and actuation are required. In addition, there are basic questions concerning unsteady fluid mechanics; these imply the need to resolve issues connected with identification of suitable signals as well as with definition of appropriate wave launchers for implementing the feedback. These issues are discussed and the results of initial successful demonstrations of active control of rotating stall in a single-stage and a three-stage axial compressor are presented. The lecture concludes with suggestions for future research on dynamic control of gas turbine engines. Author

N92-28467# GasTOPS Ltd., Gloucester (Ontario).
ENGINE PERFORMANCE AND HEALTH MONITORING MODELS USING STEADY STATE AND TRANSIENT PREDICTION METHODS
B. D. MACISAAC *In* AGARD, Steady and Transient Performance Prediction of Gas Turbine Engines 21 p (SEE N92-28458 19-07) May 1992
(AGARD-LS-183) Copyright Avail: CASI HC A03/MF A02
The role of computer modelling in the design, development, and validation of a performance monitoring system is discussed. The basic requirements of an engine health monitoring system are discussed in the context of the user environment. A form of model based on stage characteristics provides the basis for describing engine measurements. Faults are modelled in accordance with empirical data obtained from tests conducted at the stage level. The model is used to investigate various parameters that provide unambiguous identification of the fault in question. Fault libraries were developed for field use. Author

N93-13218# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Entwurfsaerodynamik.
THE JET BEHAVIOUR OF AN ACTUAL HIGH-BYPASS ENGINE AS DETERMINED BY LDA-MEASUREMENTS IN GROUND TESTS
H. HOHEISEL, K. A. BUETEFISCH (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany), B. LEHMANN (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Berlin, Germany), R. HENKE (Deutsche Airbus G.m.b.H., Bremen, Germany), H. J. ROSCHER, and U. SEELHORST (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany) *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 14 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04
The present contribution describes the measurements of a three-component laser Doppler anenometer (LDA) within the jet of a bypass engine CFM56-5 installed on an A320, in the form of ground tests. The aerodynamic data obtained at the fan exit and in two sections at the turbine nozzle exit near cruise condition allow an insight into the complete jet behavior. The velocity components in the specified position for all three coordinate directions are discussed allowing the evaluation of the radial velocity distribution and the swirl components. In addition, the important parameters of the turbulence intensity and the direction of the thrust vector are considered. Author

N93-13229# Wright Lab., Wright-Patterson AFB, OH.
HYPERSONIC PROPULSION SYSTEM FORCE ACCOUNTING
K. NUMBERS *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles p 15 (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04
A generic matrix of propulsion force accounting procedures was developed from a survey of the U.S. aerospace community. The matrix includes definitions for propulsion system and control volume boundary specification. Aerodynamic reference conditions are also discussed relative to off-design performance. The advantages and disadvantages of each of the force accounting

procedures are discussed as they apply to some typical hypersonic force accounting problems. Author

N93-13230# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).
INTEGRATION OF TURBO-RAMJET ENGINES FOR HYPERSONIC AIRCRAFT
O. HERRMANN *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 7 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A02/MF A04
The integration of turbo-ramjet engines for hypersonic transport vehicles operating in the Mach 0 to 6+ regime represents one of the most important development tasks. A survey over the variety of interacting problem areas and faculties, which have to be integrated to lead to an optimized propulsion/airframe system, is presented Author

N93-14890# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
PROPULSION AND ENERGETICS PANEL WORKING GROUP 20 ON TEST CASES FOR ENGINE LIFE ASSESSMENT TECHNOLOGY [CAS D'ESSAI POUR LA GESTION DE LA DUREE DE VIE DES MOTEURS]
Sep. 1992 232 p
(AGARD-AR-308; ISBN-92-835-0686-3) Copyright Avail: CASI HC A11/MF A03
This report presents a set of six test cases intended to provide support for the development and validation of structural analysis and life prediction codes applicable to gas turbine components. The test cases are based on actual engine simulation tests. The data bases comprising the test cases include geometric design information describing the component, rig interface information, material data, and test condition data including steady, dynamic, and thermal loading. Crack initiation and propagation data are also included. Hence, these test cases, for the first time, make available all of the component and loading information required to verify that existing codes or codes in development yield meaningful and consistent predictions. This Advisory Report was prepared at the request of the Propulsion and Energetics Panel of AGARD. For individual titles, see N93-14891 through N93-14898.

N93-14891# Army Aviation Systems Command, Cleveland, OH. Engine and Transmission Div.
INTRODUCTION TO TEST CASES FOR ENGINE LIFE ASSESSMENT TECHNOLOGY
ROBERT C. BILL *In* AGARD, Propulsion and Energetics Panel Working Group 20 on Test Cases for Engine Life Assessment Technology 6 p (SEE N93-14890 04-07) Sep. 1992
(AGARD-AR-308) Copyright Avail: CASI HC A02/MF A03
The cost of maintaining fleet readiness and the trend toward higher power to weight ratio gas turbine engines has put increased importance on component structural analysis and life prediction. Over the past decade there has been considerable progress in the development of advanced structural analysis and life prediction codes for gas turbine engine components. The six test cases comprising this document include a collection of problems that consider crack initiation and crack propagation in hot section and cold section engine components. A broad range of component configurations and loading conditions are included as well as a detailed listing of test case attributes. Author

N93-14892# Societe Nationale d'Etudes et de Construction de Moteurs Aeronautiques, Moissy-Cramayel (France). Service YLEC.
LARZAC HP TURBINE DISK CRACK INITIATION AND PROPAGATION SPIN PIT TEST
ROLAND KRAFFT *In* AGARD, Propulsion and Energetics Panel Working Group 20 on Test Cases for Engine Life Assessment Technology 13 p (SEE N93-14890 04-07) Sep. 1992
(AGARD-AR-308) Copyright Avail: CASI HC A03/MF A03
The component test of the LARZAC HP turbine disk proposed in this document provides the opportunity for validation of life prediction methodologies concerning crack initiation and propagation behavior on an area of a nickel-based refractory alloy turbine disk subjected to multi-axial loading. It should be noted, in particular, that this test, carried out under a partial vacuum at high temperature, proposes study of the natural initiation and propagation of a low-cycle fatigue crack. This test case offers the advantages of test analysis of a real turbine part, well defined test conditions, natural initiation of a crack in an area subjected to multi-axial loading leading to moderate plasticity, a well-known nickel-based material (INCONEL 718), and only two-dimensional test analysis, but requiring fine elastic-plastic modeling. The limitations of the test are that it is a component test carried out under isothermic conditions, with a simple load cycle (non-mission), and it involves a complex disk environment (recreating that of an engine) requiring modelling, of the adjacent parts to simulate realistic boundary conditions. From this study conducted by GE and RAE, it was concluded that the test case includes sufficient information to make analytic predictions of fatigue crack propagation behavior, and correlate life predictions with spin pit test results. Author

N93-14893# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).
RB 199 HIGH PRESSURE COMPRESSOR STAGE 3 SPIN PIT TESTS
JURGEN BROEDE *In* AGARD, Propulsion and Energetics Panel Working Group 20 on Test Cases for Engine Life Assessment Technology 20 p (SEE N93-14890 04-07) Sep. 1992
(AGARD-AR-308) Copyright Avail: CASI HC A03/MF A03
The RB 199 test case presented here addresses areas with stress concentration to a stress level of local elastic-plastic material behavior. The material used is a corrosion resistant steel X8CrCoNiMo11. Information about component geometry, part processing, operating conditions and history, recommendations about stress analysis and relevant boundary and thermal conditions as well as materials data are presented. This test case deals with cyclic spin pit testing conducted on the 3rd stage HP compressor disk of the TURBO UNION RB 199 engine. The tests were performed to verify disk design and life prediction under a safe life LCF lifting concept. Addressed critical areas are Bolt Holes and Rim Slots. For Bolt Hole testing the original component geometry was modified slightly, for Rim testing significantly to ensure component failure to occur in the area under investigation and local stress distribution as under engine operating conditions. Following an independent analysis, it was concluded that the test case includes sufficient information to generate a viable stress analysis model, generate concentrated stress factors, and correlate life predictions with the spin pit test results. Analyses and the materials data provided in the test cases were used to predict the disk lives for the spin pit testing within 10 percent of the observed lives. Author

N93-14894# General Electric Co., Cincinnati, OH. Aircraft Engines.
CF6-6 HIGH PRESSURE COMPRESSOR STAGE 5 LOCKING SLOT CRACK PROPAGATION SPIN PIT TEST
PAUL A. DOMAS *In* AGARD, Propulsion and Energetics Panel Working Group 20 on Test Cases for Engine Life Assessment Technology 26 p (SEE N93-14890 04-07) Sep. 1992
(AGARD-AR-308) Copyright Avail: CASI HC A03/MF A03
The CF6-6 High Pressure Compressor Stage 5 Locking Slot Crack Propagation Spin Pit test case provides the opportunity for validation of stress analysis and crack propagation life prediction methodologies for a complex geometry, titanium material, gas turbine aircraft engine component. The case addresses crack growth from an artificial crack starter notch under isothermal, constant amplitude, continuous (no dwell period), cyclic testing in a partially evacuated spin pit test facility. The most outstanding attribute of the case in the comprehensive crack growth measurement data available in 200 cycle increments throughout the 7355 cycle test duration. The test case included use of actual hardware (field returned, titanium material, engine part); complex local part geometry involving a decaying stress gradient; an elastic-plastic stress level (local area yielding); realistic surface conditions (milled and shot peened surface), and assessment of a significant failure mode. To evaluate this test case, a two-dimensional axisymmetric finite element stress analysis of the compressor spool was completed followed by a two-dimensional finite element analysis of the concentration effect of the loading slot. These results were used to calculate the crack propagation behavior from the crack starter notches introduced at the loading slots. Factors to account for the effect of shot peening were

derived empirically from the results given for the notched bend specimen. These factors were used in the component life calculation which resulted in a prediction within 13 percent of the observed life. The assessment confirmed the suitability of this test case. Author

N93-14895# Rolls-Royce Ltd., Bristol (England).
RB211-524B DISC AND DRIVE CONES HOT CYCLIC SPINNING TEST
LAWRENCE M. JENKINS and S. E. CROW *In* AGARD, Propulsion and Energetics Panel Working Group 20 on Test Cases for Engine Life Assessment Technology 28 p (SEE N93-14890 04-07) Sep. 1992
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The details of component dimensions, loading, material properties, and general arrangements required to perform a stress analysis on the RB211-524 HPT Disc and Drive Cones are presented. The experimental assembly was modelled using finite element stressing techniques at a temperature of 500 C, with the radial load being applied for the dummy blade weights. The test was halted after 3734 rig cycles due to LCF cracking at the runout of the bolt hole boss blend radius to the rear face diaphragm of the disc. Author

N93-14896# General Motors Corp., Indianapolis, IN. Allison Gas Turbine Div.
ENGINE LIFE ASSESSMENT TEST CASE TF41 LP COMPRESSOR SHAFT TORSIONAL FATIGUE
WILLIAM H. PARKER *In* AGARD, Propulsion and Energetics Panel Working Group 20 on Test Cases for Engine Life Assessment Technology 63 p (SEE N93-14890 04-07) Sep. 1992
(AGARD-AR-308) Copyright Avail: CASI HC A04/MF A03

The test case presented here provides an example for crack initiation and crack growth of a shaft loaded with major, zero to maximum, torsional cycles with steady axial load and high cycle minor torsional cycles superimposed. The TF41 LP compressor drive shaft was tested as part of a U.S. Air Force Life Extension Program in the early to mid 1980s. This test program provided a controlled set of fatigue testing information and material characterization data which form the basis of the test case. Details of the engine shaft are presented along with pertinent processing information. The test setup and program are described in sufficient detail to permit users to model the component and predict the state of stress. Material data are presented with enough detail so that fatigue life models can be used to predict the shafting life and comparisons with test results can be made. Author

N93-14897# Pratt and Whitney Aircraft, West Palm Beach, FL. Government Engine Business.
F100 SECOND STAGE FAN DISK BOLTHOLE CRACK PROPAGATION FERRIS WHEEL TEST
THOMAS E. FARMER *In* AGARD, Propulsion and Energetics Panel Working Group 20 on Test Cases for Engine Life Assessment Technology 48 p (SEE N93-14890 04-07) Sep. 1992
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This test case provides the opportunity for the evaluation of the overall stress state in a typical 'fracture critical' gas turbine engine rotor component and residual crack propagation life assessment at the bolthole for a simulated low cycle fatigue engine operation mission cycle. Ferris wheel testing provides the crack propagation data to which the prediction is correlated. In addition, an overload hot pre-spin treatment of the disk is evaluated as a means of establishing an induced beneficial near surface compressive residual stress at the bolthole to enhance the crack propagation life. The F100 2nd stage fan disk was tested as part of the U.S. Air Force Damage Tolerant Design for Cold-section Turbine Engine Disks Program AFWAL-TR-81-2045 in the late 70s. The component geometry, part processing, test rig set-up, operating conditions and environment, and materials data are presented in sufficient detail to allow users to model the component and predict the state of stress throughout the body of the disk with particular attention to the bolthole outer diameter location of interest. Solution of the stress state at the bolthole O.D. for the simulated mission cycle and use of crack propagation rate models allow prediction of the residual life from pre-cracks and make comparisons to actual test data. Author

N93-14898# Hawker Siddeley Canada Ltd., Toronto (Ontario). Orenda Div.
IN-SERVICE CONSIDERATIONS AFFECTING COMPONENT LIFE
RAJ THAMBURAJ *In* AGARD, Propulsion and Energetics Panel Working Group 20 on Test Cases for Engine Life Assessment Technology 16 p (SEE N93-14890 04-07) Sep. 1992
(AGARD-AR-308) Copyright Avail: CASI HC A03/MF A03

It is believed that the cases reported will be the forerunner of a number of future studies dealing with more complex combinations of factors that need to be considered to assess the life of a gas turbine component in actual service. Some of these considerations are discussed here, in relation to the test cases detailed in earlier chapters. While the focus is upon discs and spacers, to maintain a close relationship with the test cases presented earlier for other engines, blade life prediction is also discussed. Where appropriate, examples were drawn from experience in J85 and F404 engines operated in Canada. This paper considers various practical aspects of life prediction which merit further investigation. These are as follows: small crack behavior; the effect of loading conditions, multiaxial loading, HCF-LCF interactions, creep-fatigue and creep-fatigue-environment interactions; microstructural effects, long term service exposure effects, grain size, and grain shape effects, anisotropic behavior and single crystal turbine blades; coating effects; defects and damage tolerance; inspection sensitivity and reliability effects; residual stress effects; effects of repair; and usage monitoring. Author

N93-17613# Centre National de la Recherche Scientifique, Paris (France). Ecole Centrale Paris.
COMBUSTION INSTABILITIES IN A SIDE-DUMP MODEL RAMJET COMBUSTOR
J. M. SAMANIEGO, B. YIP, T. POINSOT, and S. CANDEL *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 17 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

Combustion instabilities are often observed in coaxial and side-dump combustors and can be detrimental to their performance. This study is aimed at identifying the physical mechanisms underlying combustion instabilities in these geometries. Recent studies performed on side-dump geometries have focused on hydrodynamic instabilities under non-reacting conditions. The present work was conducted on a two-dimensional two-inlet side-dump combustor, fed with a premixture of air and propane in order to examine reacting flow instabilities. Results from a stable combustion regime are presented in order to provide a basis for comparison with a low-frequency instability mode (520 Hz) which occurs at other combustor operating conditions. The flowfield structure is investigated using high speed Schlieren visualization and conditional C2 imaging. Simultaneous pressure, inlet velocity, and global C2 emission measurements are used to investigate the nature of the instability. Different processes involved in the instability mode are identified such as the acoustics of the combustor, the oscillatory motion of the jets underlying periodic jet-on-jet impingement and a complex behavior of the reaction zones. Furthermore, by obtaining an experimental local Rayleigh index distribution, it has been possible to identify the driving mechanisms of this instability. Author

N93-17615# Rheinmetall G.m.b.H., Duesseldorf (Germany).
RAMJET PROPULSION FOR ADVANCED PROJECTILES
R. MOENIG and M. MOLL *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 9 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A02/MF A03

The increasing effectiveness of future defense systems will lead to projectiles with extremely high impact energy, reduced flight times, and extended ranges. Gun launched projectiles using ramjet propulsion, show promising capabilities in weight, cost, and hit accuracy. If high maximum range and low crosswind sensitivity of projectiles is of primary interest, a compensation of drag can be obtained by ramjet propulsion at low fuel-to-air ratio. Moreover, with respect to applications against armored vehicles ramjet engines operating at nearly stoichiometric conditions, can be even used to increase the kinetic energy of KE-rods. The first part of the paper gives a survey on the main design objectives of ram-propulsion for projectile applications. A detailed theoretical analysis of advantages and limitations is presented for high

performance ramjets. The second part deals with ramjet applications for artillery, air defense, and anti-armor weapons. Due to the high initial velocity provided by guns, ram-propulsion proves to be a very promising and efficient tool in order to meet the demands of future defense systems. Author

N93-17616# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).
COMPARISON OF PERFORMANCES OF DIFFERENT CIRCULAR INTAKES
HERMANN L. WEINREICH and KLAUS TREISCH (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Berlin, Germany) *In* AGARD, Airbreathing Propulsion for Missiles and Projectiles 8 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A02/MF A03

Different circular front intakes with shock on lip Mach numbers ranging from 4.5-5.57 were investigated at DLR-Cologne and MBB under funding of the German MOD. The closeable front intake concept (born in 1985) offers high performance at Mach 3.6 transition in combination with exceptionally low drag during boost and cruise. Starting of the essential internal supersonic compression process could be achieved during initial centerbody translation at limited internal contraction and small capture area. A variety of corresponding Hy X intake models having different shock on lip Mach numbers, cowl angles, internal contractions, internal area distributions, and cowl lip bluntness data were tested between Mach 3.5 and 4.5 and gave experience on starting phenomena and performance. Fixed geometry intakes with external compression and quite different cowl angles (RH3A with cylindrical cowl, RH3C with large cowl angle) exhibited comparable or even better total pressure recoveries. The supercritical pre-entry drag characteristics below shock on lip Mach numbers however look most unfavorable. Without consideration of incidence characteristics and the problems associated with closure of intake entrance area during boost, the RH3A-intake could be used instead of the Hy X-type intake for medium range air to ground missiles. The RH3C-intake offers the highest value of total pressure recovery due to maximum external compression and proper cowl alignment. The corresponding high wave drag however prohibits any useful application of this type of intake. Author

N93-17620# Microturbo, Toulouse (France).
SIMPLE AND POWERFUL TURBOJET WITH FOUR STAGE AXIAL COMPRESSOR AND AXIAL FLOW TURBINE FOR THE PROPULSION OF SUBSONIC MISSILES [TURBOREACTEUR SIMPLE ET PERFORMANT A COMPRESSOR AXIAL QUADRI-ETAGE ET TURBINE AXIALE POUR LA PROPULSION DE MISSILES SUBSONIQUES]
JEAN-PAUL LOPEZ and CHARLES MISCHEL *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 20 p (SEE N93-17607 05-20) Sep. 1992 In FRENCH
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

The design and development of turbojet engines for missile and target drone propulsion is a field in which MICROTURBO enjoys considerable success. A MICROTURBO engine was selected and is in current development for the APACHE standoff missile. This new single-flow, single-spool turbojet produces 550 daN at Mach 0.8; this gives an SFC figure of 1.10 kg/daN/h at 550 daN and SL Static, which drops to the region of 1 kg/daN/h at 300-400 daN. All this is accomplished by an engine that has a diameter of 343 mm. This preview outlines the tasks carried out to obtain the optimum thermodynamic definition and mechanical design of the engine. Extensive experience in the design of three and four stage compressors of this type was gained by MICROTURBO on their TRI 60 engine family. This experience was used as a basis for the conceptual design of the subject compressor with concurrent intensive use of the 3D EULER code developed by ONERA. The turbine, pre-dimensioned using conventional design methods, was also optimized by means of the EULER code. In a relatively short time, each compressor stage was manufactured then tested separately in the RACE test cell at the CEPr facilities in France, this being closely followed by complete compressor testing, during which performance expectations were met and even exceeded. Major mechanical design requisites for this life-limited engine were minimum maintenance, guaranteed performance, and low-cost production. A feasibility study on production cost effectivity, involving close liaison between the design office and methods department, was initiated in the early stage of the program. Using data provided by external suppliers, various solutions were investigated, the final selection taking into account production cost and risk factors relative to engine and/or missile integration. The result of this investigation is the wide use of castings for rotors, stators, and casings. Maximum simplicity was achieved for engine systems by designing in features such as windmill start capability, a virtually direct drive transmission to the fuel pump and the alternator, and finally, the elimination of the oil lube system. Author

N93-17621# Sundstrand Turbomach, San Diego, CA. Aerothermo Conceptual Design.
SMALLER EXPENDABLE TURBOJETS
C. RODGERS *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 12 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

One current focus of propulsion research is to increase gas turbine power density through improved aerothermodynamic component technologies and lower density, higher temperature materials. The objective of increased power density is to decrease engine size for a given output power. For example, increasing power density 100 percent, which is being projected by the 21st century, would be accompanied by a 40 percent reduction in engine size and 40 percent increase in engine speed. The trend towards reduced engine size tasks the ability of the turbojet designer to maintain the high levels of component efficiencies needed and to achieve the projected power density goals. Furthermore, parallel technology improvements projected in propulsion vehicle, system, and electronics technologies, further anticipate engine size reduction. Smaller, smarter airbreathing tactical missiles are being proposed and developed. They will function for various operational duties currently performed by larger, limited range missiles or manned surveillance and interdiction aircraft. The extreme compactness of these advanced missiles requires relatively high power density small turbojets. Several design configuration options are possible for these turbojets including centrifugal and axial turbomachinery compressor and turbines, straight annular and reverse flow annular combustors, and fuel injectors, etc. The attributes of candidate configurations are discussed with respect to maximum thrust per frontal area and low manufacturing cost. Author

N93-17622# Centre d'Etudes et de Recherches, Toulouse (France).
PREDICTION OF THE PERFORMANCES IN COMBUSTION OF RAMJETS AND STATO-ROCKETS BY ISOTHERMAL EXPERIMENTS AND MODELING [PREDICTION DES PERFORMANCES EN COMBUSTION DE STATO-REACTEURS ET STATO-FUSEES PAR EXPERIMENTATIONS ISOTHERMES ET MODELISATIONS]
P. HEBRARD, G. LAVERGNE, A. TORGUE, F. BISMES, and G. HEID *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 9 p (SEE N93-17607 05-20) Sep. 1992 In FRENCH
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This publication presents a semi-empirical approach aimed at studying the internal aerodynamic characteristics of combustion chambers and using this information to predict the performance of various ramjet and strato-rocket combustion chambers. The step suggested, which appeared to be completely operational for numerous treated cases, is based on the joint use of experiments, carried out in isothermal simulated conditions, and of a one dimensional modeling using the concept of elementary jet engines. The experiments are undertaken on hydraulic test rigs or aerodynamic installations using reduced scale models. Conventional techniques of visualization then make it possible to reach the first qualitative description of the flow. Those are supplemented by a certain number of measurements resulting from image processing carried out on preceding visualizations. This quantitative information consisting of the distribution of flow, residence time, and concentration, is then translated into the form of input data for computer code. This calculation, carried out the second time, can use complex chemical kinetics to describe combustion and thus makes it possible to predict, with a good degree of accuracy, the total performance of the chamber (stability limits, combustion output as a function of operating characteristics, etc.,). The interest of such a step during the preliminary draft stage was shown for a significant number of chambers by

comparing the results obtained in combustion with those resulting from calculation. Transl. by FLS

N93-29926# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
HEAT TRANSFER AND COOLING IN GAS TURBINES [LE TRANSFERT THERMIQUE ET LE REFROIDISSEMENT DANS LES TURBINES A GAZ]
Feb. 1993 492 p 80th Symposium held in Antalya, Turkey, 12-16 Oct. 1992
(AGARD-CP-527; ISBN-92-835-0701-0) Copyright Avail: CASI HC A21/MF A04

The symposium was arranged in the following sessions: turbine blades--external heat transfer; turbine blades--internal heat transfer; measurement techniques; rotating disks, labyrinth seals, and shafts; combustors; design, interactions; and prediction methods. Heat transfer and cooling in gas turbines are still key factors for achieving high performance, increased life, and improved reliability. Any progress in this field will lead to a reduction of maintenance cost and fuel consumption. The purpose of the symposium was to bring together experts from industry, research establishments, and universities to discuss fundamental and applied heat transfer problems relevant to gas turbines, to exchange practical experience gained, and to review the state of the art. For individual titles, see N93-29927 through N93-29964.

N93-29927# Rensselaer Polytechnic Inst., Troy, NY.
KEYNOTE ADDRESS: UNSTEADY, MULTIMODE TRANSITION IN GAS TURBINE ENGINES
ROBERT E. MAYLE *In* AGARD, Heat Transfer and Cooling in Gas Turbines 7 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

A theory for unsteady, multimode transition on gas turbine airfoils is presented. The theory, which provides a correction to the Mayle-Dullenkopf multimode model, considers a more physically correct viewpoint by taking into account the periodic disturbance caused by both the wake-induced turbulent strips and the 'becalmed' flow following them. In addition, a comparison of the theory with data is provided, which shows excellent agreement, and results illustrating the effects of transition onset distance and wake-passing Strouhal number on multimode transition are presented. Derived from text

N93-29928# Defence Research Agency, Farnborough, Hampshire (England). Aerodynamics and Propulsion Dept.
HEAT TRANSFER AND AERODYNAMICS OF A 3D DESIGN NOZZLE GUIDE VANE TESTED IN THE PYESTOCK ISENTROPIC LIGHT PISTON FACILITY
K. S. CHANA *In* AGARD, Heat Transfer and Cooling in Gas Turbines 11 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

In HP turbines, predictions of the heat transfer to the blade and endwalls is particularly important for an accurate assessment of turbine component life. On the endwalls, there are often complex 3D (secondary) flows present which make predictions of heat transfer particularly difficult. A detailed investigation of this area has been carried out on a fully annular cascade of highly 3D nozzle guide vanes. Measurements were made on the vane and endwalls to determine heat transfer and aerodynamic characteristics. Testing was conducted in a short duration Isentropic Light Piston Test Facility, at engine representative Reynolds number, Mach number, and gas-to-wall temperature ratio. Interpreted test data are compared with computations obtained at test conditions. Author (revised)

N93-29929# Minnesota Univ., Minneapolis, MN. Dept. of Mechanical Engineering.
VORTEX STRUCTURE AND MASS TRANSFER NEAR THE BASE OF A CYLINDER AND A TURBINE BLADE
M. Y. JABBARI and R. J. GOLDSTEIN *In* AGARD, Heat Transfer and Cooling in Gas Turbines 14 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by AFOSR
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

Results of naphthalene sublimation measurements and flow visualization studies near the base of round and a square cylinder mounted on a flat plate are compared with similar measurements in the endwall region of a turbine blade. Differences and similarities of the flow and mass transfer are discussed. Samples of mass transfer distribution and visualization results in the region are provided. Supported by the sublimation and the flow visualization results models for the vortex structure in the flow are suggested. Derived from text

N93-29930# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
THERMAL EFFECTS OF A COOLANT FILM ALONG THE SUCTION SIDE OF A HIGH PRESSURE TURBINE NOZZLE GUIDE VANE
T. ARTS and I. LAPIDUS (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche, France.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 8 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by SNECMA
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

The purpose is to try to describe some of the influences on external convective heat transfer of a coolant film whose position varies along the suction side of a high pressure turbine nozzle guide vane. The measurements were performed in the short duration Isentropic Light Piston Compression Tube Facility CT-2 of the von Karman Institute. The effects of external and internal flow are considered in terms of Mach number, Reynolds number, freestream turbulence intensity, blowing rate, and coolant to freestream temperature ratio. The way to evaluate those results in terms of heat transfer coefficient is finally discussed. Author (revised)

N93-29931# Poitiers Univ. (France). Lab. d'Etudes Aerodynamiques.
EXPERIMENTAL STUDY OF HEAT TRANSFER CLOSE TO A PLANE WALL HEATED IN THE PRESENCE OF MULTIPLE INJECTIONS (SUBSONIC FLOW) [ETUDE EXPERIMENTALE DU TRANSFERT DE CHALEUR PRES D'UNE PAROI PLANE CHAUFFEE EN PRESENCE D'INJECTIONS MULTIPLES (ECOULEMENT SUBSONIQUE)]
E. FOUCAULT, P. DENIBOIRE, J.-L. BOUSGARBIES, J.-J. VULLIERME, and E. DORIGNAC *In* AGARD, Heat Transfer and Cooling in Gas Turbines 10 p (SEE N93-29926 11-07) Feb. 1993 In FRENCH
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

The results of a detailed experimental study of the aerodynamic and thermic fields within the boundary layer of a plane wall heated in the presence of localized injections of hot air are presented. For two values of the ratio of jet speed/main flow (0.6 and 1.6) the three components of the flight path vector and the local temperature of the flow are measured in many positions, respectively by Doppler laser anemometry using a cold probe wire. A map of the temperature of the plane wall is obtained by means of an infrared camera. The results show the strongly 3D aspect of the flow downstream from the jet which is dominated by the presence of swirling structures. These last areas generate strong rates of turbulence and have a great influence on the temperature field in the wake of the jets. For the largest of the two speed ratios considered, the cross-flow penetrates under the jets downstream from the injection openings and thus, is in opposition to the heat transfer. Author (revised)

N93-29932# Massachusetts Inst. of Tech., Cambridge, MA. Gas Turbine Lab.
THE INFLUENCE OF NON-UNIFORM SPANWISE INLET TEMPERATURE ON TURBINE ROTOR HEAT TRANSFER
G. R. GUENETTE, G. PAPPAS, and A. H. EPSTEIN *In* AGARD, Heat Transfer and Cooling in Gas Turbines 10 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by Rolls-Royce, Inc.
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The influence of a spanwise varying, circumferentially uniform inlet total temperature distortion was measured on a transonic turbine stage in a short duration turbine test facility. Large levels of distortion were found to increase rotor blade heat transfer, especially on the pressure surface. A three-dimensional, steady, multi-blade row, Euler code and a streamline curvature calculation were used to interpret the data but did not account for all of the heat transfer increase observed. Author (revised)

N93-29933# Naval Air Warfare Center, Trenton, NJ. Aircraft Div.
DETERMINATION OF SURFACE HEAT TRANSFER AND FILM COOLING EFFECTIVENESS IN UNSTEADY WAKE FLOW CONDITIONS
M. SAUTNER, S. CLOUSER, and J. C. HAN (Texas A&M Univ., College Station.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 12 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

The effect of unsteady wake flows on blade heat transfer and film cooling effectiveness was experimentally determined by using a spoked-wheel type wake generator. The experiments were performed with a five airfoil linear cascade at the Texas A&M University low speed wind tunnel facility. The mainstream Reynolds number based on airfoil chord length was about 3 x 10 exp 5. The wake Strouhal number was varied between 0 and 0.4 by changing the rotating wake passing frequency. A hot wire anemometer system was located at the cascade inlet to detect the instantaneous velocity, phase-averaged mean velocity, and turbulence intensity induced by the passing wake. A pressure tap instrumented blade was used to measure the surface static pressure distributions and compared well with predicted velocity distributions in the cascade. An instrumented blade without film holes equipped with a thin foil thermocouple was used to determine the surface heat transfer coefficient distributions. The results show that the periodically passing wake promotes earlier boundary layer transition, causing much higher heat transfer on the suction surface. The passing wake also significantly enhances the heat transfer on the pressure surface. The other thin foil thermocouple instrumented blade contained several rows of film cooling holes at the stagnation region and on both the suction and pressure surfaces, and was employed to determine the film cooling effectiveness distributions. The results show that the strong passing wake interacts with the film layer and causes a relatively lower film effectiveness on both the suction and pressure surfaces for all three blowing ratios studied (M = 0.4, 0.8, and 1.2).
Derived from text

N93-29934# Oxford Univ., Oxford (England). Dept. of Engineering Science.
MEASUREMENT OF TURBULENT SPOTS AND INTERMITTENCY MODELLING AT GAS-TURBINE CONDITIONS
J. P. CLARK, J. E. LAGRAFF (Syracuse Univ., NY.), P. J. MAGARI, and T. V. JONES *In* AGARD, Heat Transfer and Cooling in Gas Turbines 14 p (SEE N93-29926 11-07) Feb. 1993
(Contract(s)/Grant(s): F49620-92-J-0079; AF-AFOSR-0427-89)
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

Measurements have been made of instantaneous heat-transfer rates to a flat-plate surface under a transitional boundary layer. The thin-film surface instrumentation used in the study was capable of time-resolving the effects of changes in the heat-transfer rate within an accuracy of 10 microseconds. The tests were conducted in the Oxford University 6 inch Isentropic Light-Piston Tunnel (ILPT) under simulated gas turbine Reynolds numbers, Mach numbers, gas-to-wall temperature ratios, and pressure gradients. The ability to observe and track the end stage of the transition process (i.e., turbulent spots) in a laminar boundary layer undergoing transition allowed turbulent-spot convection speeds and spreading angles to be estimated. In these tests, the important fluid-dynamic parameters of Mach number, Reynolds number, and streamwise pressure gradient were varied independently over a wide range of values characteristic of those encountered in the turbine environment. Using quantitative values of the measured turbulent-spot characteristics, a simple time-marching code was developed based on Emmons' turbulent-spot theory to estimate the intermittency.
Derived from text

N93-29938# Manchester Coll. of Science and Technology (England).
TURBULENT FLOW AND HEAT TRANSFER IN IDEALIZED BLADE COOLING PASSAGES
T. BO and B. E. LAUNDER *In* AGARD, Heat Transfer and Cooling in Gas Turbines 16 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by Ministry of Defence and Rolls-Royce Ltd.
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The paper brings together recent research at UMIST directed at the prediction of flow through tight, square sectioned U-bends rotating in orthogonal mode. The cases of flow through rotating straight ducts and stationary U-bends are considered first to allow comparison with experimental data; finally, having demonstrated the level of accord achieved with experiment, predictions for the rotating U-bend are provided. A fairly simple turbulence model was adopted with the usual high Reynolds number k-epsilon model being interfaced with a 1-equation near-wall model. To achieve, in the case of the U-bend, grid independent behavior with the available computer core, a bounded third-order discretization of convective transport had to be applied to all dependent variables. The agreement with the available experimental data is broadly satisfactory in the case of the rotating straight duct (the substantial modifications to the Nusselt number on the pressure and suction faces of the duct due to Coriolis and buoyant forces being well reproduced. Agreement is less complete in the case of the U-bend but even so, the predicted levels of Nusselt number and the distribution of velocity downstream of the bend are broadly in line with experiment. The results point to the desirability of incorporating second-moment closure into the bend-flow calculations as models of this type have a track record of capturing the sensitivity of the turbulent stresses to complex strains better than the eddy viscosity model adopted here.
Author (revised)

N93-29939# Fiat Aviazione S.p.A., Turin (Italy).
COOLING GEOMETRY OPTIMIZATION USING LIQUID CRYSTAL TECHNIQUE
G. LODIGIANI, A. TROVATI, L. PACI, and P. PIRRELLI (Elasis S.C.p.A., Brindisi, Italy.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 12 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

Experimental results concerning the cooling performance of jet engine blading internal passages are presented. Use was made of the Liquid Crystal Transient Technique in order to obtain detailed information about heat transfer coefficients on the internal blade surfaces in presence of turbulence promoters. A peculiar behavior of the cooling channels with turbulators was detected, which reduces the expected heat transfer effectiveness. Heat transfer experimental results, reproducing actual engine operating conditions, were employed to predict the blade metal temperature: cooling flow parameters and internal channel characteristics were therefore tuned in order to attain a suitable metal temperature distribution, and to optimize the cooling effectiveness. The outcome of experimental and calculation work was then compared to the engine test blade surface temperature distribution, obtained by means of thermal paints. The comparison showed fairly good agreement, demonstrating once more the usefulness of the Liquid Crystal Transient Technique in allowing designers to improve present blade cooling devices.
Author (revised)

N93-29943*# Arizona State Univ., Tempe, AZ. Dept. of Mechanical and Aerospace Engineering.
LOCAL HEAT TRANSFER MEASUREMENT WITH LIQUID CRYSTALS ON ROTATING SURFACES INCLUDING NON-AXISYMMETRIC CASES
D. E. METZGER and Y. K. KIM *In* AGARD, Heat Transfer and Cooling in Gas Turbines 11 p (SEE N93-29926 11-07) Feb. 1993 Sponsored by NASA. Marshall Space Flight Center and Rockwell International Corp.
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

An overview and summary of test methods and results are given for the problem of measuring local heat transfer on rotating surfaces that model gas turbine engine disks. Disk cavity situations generically similar to those encountered in the high pressure stage disk cooling are considered, with cooling air supplied both at or near the wheel centerline as well as through single or multiple jets impinging outboard on the wheel near the blade attachment region. In some situations provision has been made for ingestion

into the disk-cavity from the gas path region radially outboard of the disk. Local heat transfer rates in all cases are determined from the color display from a thin coating of encapsulated liquid crystals sprayed onto the disk, in conjunction with use of a video camera and computer vision system. For cases with axisymmetric disk surfaces, the coated surfaces are illuminated and viewed continuously, and detailed radial distributions of local Nusselt number are obtained. For non-axisymmetric disk surfaces, such as encountered in the vicinity of bolt heads, the disk is illuminated with stroboscopic light, and a method has been developed and used to synchronize the computer frame grabber with the illumination. Author (revised)

N93-29946# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).

TRANSIENT THERMAL BEHAVIOUR OF A COMPRESSOR ROTOR WITH AXIAL COOLING AIR FLOW AND CO-ROTATING OR CONTRA-ROTATING SHAFT

C. BURKHARDT, A. MAYER, and E. REILE *In* AGARD, Heat Transfer and Cooling in Gas Turbines 9 p (SEE N93-29926 11-07) Feb. 1993

(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

Heat transfer measurements were made in a five-cavity compressor drum rig, in which cooling air passed axially through the center of the discs. The rig also contained a central drive shaft which could be either co- or contrarotated. Tests were conducted for different mass flow rates, rotational speeds and air temperatures. Typical engine conditions for steady state and transient operating conditions were simulated. Local Nusselt numbers were obtained for the discs of one cavity and compared with other published results. Furthermore an investigation into the effect of co- and contrarotating shaft on the surface temperatures of the discs and on the Nusselt number distribution was also carried out. It was found that the direction of rotation and speed of the shaft influenced the disc temperatures as well as the Nusselt numbers. Author

N93-29947# Office National d'Etudes et de Recherches Aerospatiales, Bagneux (France). Direction de l'Energetique.

AEROTHERMIC CALCULATIONS OF FLOWS IN INTERDISC CAVITIES OF TURBINES [CALCULS AEROTHERMIQUES D'ECOULEMENTS DANS DES CAVITES INTERDISQUES DE TURBINES]

D. DUTOYA and P. PONCELINDERAUCOURT (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel, France.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 9 p (SEE N93-29926 11-07) Feb. 1993 In FRENCH

(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

The operating temperatures of turboshaft engines oblige the manufacturers to cool the parts of the engine located downstream from the combustion chamber and in particular the turbines. Knowledge of the air flow in the air ventilation paths is essential to optimize the cooling of the engines. In order to precisely determine the phenomena of heat exchanges and the aerodynamic forces on the walls of complex cavities, SNECMA uses the MATHILDA code developed with ONERA. The MATHILDA code solves the three dimensional Navier-Stokes equations for flows of compressible fluid. The equations are treated using a finite volume method accomplished on a mesh structure. The resolution scheme is decentered by the order of 2. An implicit method of the ADI type makes it possible to stabilize and accelerate the calculation. This article presents the work of the validation of the MATHILDA code for applications to the flows in interdisc cavities. The cases presented were studied by the implementation of the axisymmetric two-dimensional version. Two types of experimental cavities served as the validations, rotor/stator cavities and rotor/rotor cavities. The solutions obtained, compared with the experimental measurements, are satisfactory, from an aerodynamic point of view and a thermal point of view. The last calculation, on a real configuration of the internal cavity of the engine, makes it possible to apprehend the difficulties encountered in the implementation of this type of modeling, and to measure the contribution of the code solving the Navier-Stokes equations to the description of the cooling flows. Transl. by FLS

N93-29949# Rolls-Royce Ltd., Derby (England).

MODELLING THERMAL BEHAVIOUR OF TURBOMACHINERY DISCS AND CASINGS

R. D. MONICO and J. W. CHEW *In* AGARD, Heat Transfer and Cooling in Gas Turbines 10 p (SEE N93-29926 11-07) Feb. 1993

(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

The thermal behavior of discs and casings in gas turbine engines has important effects on engine performance and integrity and theoretical or computer modelling of these effects is an essential part of the design process. In this paper the current status of thermal modelling is reviewed, problem areas are identified, examples of where application of the latest numerical and modelling techniques have led to improvements are given, and prospects for further developments are discussed. It is concluded that, although recent research and computing advances are improving the predictive capability, considerable scope for further improvement remains. Author

N93-29950# Bath Univ. (England). School of Mechanical Engineering.

FLOW AND HEAT TRANSFER BETWEEN GAS-TURBINE DISCS

X. GAN, M. KILIC, and J. M. OWEN *In* AGARD, Heat Transfer and Cooling in Gas Turbines 11 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by Ministry of Defence and Science Research Council

(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

The paper provides both a brief review of some recent research into the flow and heat transfer associated with the turbine and compressor discs of gas turbine engines and some new results for flow between contra-rotating turbine discs. Elliptic solvers, parabolic solvers and integral methods have all been applied successfully to some important axisymmetric boundary-layer-dominated flows, and multigrid elliptic solvers used in conjunction with parallel computers offer great promise for the future computation of nonaxisymmetric flows. LDA velocity measurements and computations have given fresh insight into the flow between contra-rotating turbine discs. Batchelor-type flow, in which there are boundary layers on the discs and a shear layer in the midplane, has been computed for laminar flow but has not been observed in practice, even at local rotational Reynolds numbers as low as 2.2 x 10(exp 4). The actual flow structure comprised radial outflow in boundary layers on the discs and a central core of radial inflow in which rotational effects were weak. Although the flow in the core was always turbulent, the flow in the boundary layers was laminar for rotational Reynolds numbers up to at least 1.2 x 10(exp 5). Agreement between the computed turbulent velocities and the measured values was good for Reynolds numbers above 4.5 x 10(exp 5). Author (revised)

N93-29951# Karlsruhe Univ. (Germany). Lehrstuhl und Inst. fuer Thermische Stroemungsmaschinen.

HEAT TRANSFER AND LEAKAGE IN HIGH-SPEED ROTATING STEPPED LABYRINTH SEALS

W. WASCHKA, S. WITTIG, S. KIM, and T. SCHERER *In* AGARD, Heat Transfer and Cooling in Gas Turbines 10 p (SEE N93-29926 11-07) Feb. 1993

(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

A new experimental and numerical research program was conducted to determine the effects of rotation on the leakage loss and the heat transfer coefficients of compressible flows in modern high performance labyrinth seals. In this study, the interest is focused on divergent shaped stepped labyrinth seals. That type of labyrinth seal is the last one within a row of different labyrinth seals, investigated at the University of Karlsruhe: straight-through, staggered labyrinth seals and convergent shaped stepped labyrinth seals have been the other geometries. For heat transfer and leakage loss measurements our high temperature test facility was used, providing realistic conditions of gas temperatures, pressure ratios as well as a wide range of axial and peripheral Reynolds numbers. In addition, numerical codes have been verified by experimentally obtained data. Heat transfer coefficients for the stator and the rotor are derived utilizing the well-known standard k-epsilon model and the Stanton-analogy. This report discusses some new rotational effects, which are significant for the divergent shaped seal. In addition, these results are compared with those

obtained from our other seal geometries studied.
Author (revised)

N93-29957# Alfa Romeo S.p.A., Naples (Italy). Research and Development.
AERO-THERMAL DESIGN OF A COOLED TRANSONIC NGV AND COMPARISON WITH EXPERIMENTAL RESULTS
S. COLANTUONI, A. COLELLA, L. DINOLA, D. CARBONE, and D. MAROTTA *In* AGARD, Heat Transfer and Cooling in Gas Turbines 25 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

The aerothermal design process applied to a Nozzle Guide Vane of a gas-generator axial-flow turbine for a compact advanced technology core engine is described. The principal characteristics of the NGV are: Overall Tip Radius, 108.8 mm; Blade height, 19.7 mm; Blade aspect ratio, 0.53; Solidity, 1.37; Mean Exit isentropic Mach Number, 0.95; Inlet Temperature, 1450K. The NGV is cooled by a combination of different solutions, like impingement cooling and film-cooling on the front side, and forced convection on the rear side, followed by a cooling ejection at pressure side near the trailing edge. Representative results of the computational fluid-dynamics and of the thermal analysis of the NGV blade, together with some experimental data obtained from component test rig and engine demonstrator are presented and discussed.
Author (revised)

N93-29958# ABB Power Generation, Inc., Baden (Switzerland).
THE AERODYNAMIC EFFECT OF COOLANT EJECTION IN THE LEADING EDGE REGION OF A FILM-COOLED TURBINE BLADE
A. BEECK, L. FOTTNER (Munich FAF Univ., Neubiberg, Germany.), E. BENZ (Karlsruhe Univ., Germany.), and S. WITTIG (Karlsruhe Univ., Germany.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 10 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by Bundesministerium der Verteidigung
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

Air ejection for film-cooling affects the aerodynamic behavior of the blading by the mixing of the coolant with the mainstream as well as by the interaction between the jet and the boundary layer. The main objective is to receive more information on the flow field in the leading edge region. The focus is the aerodynamic behavior of ejection in the stagnation region. A Navier-Stokes code was used to evaluate the flow field considering the ejection. The calculated results are compared with experimental investigations. Cold gas experiments were conducted in a cascade wind tunnel on three large scaled turbine blades with slotted leading edges. The mass flux ratio was varied from 0.0 to 2.5 to simulate film cooling effects. A high resolution of the flow field especially close to the wall (nearest distance: 50 microns) was achieved by Laser-2-Focus measurements. The pressure distributions on the blade surface and in the wake were measured in order to determine the overall behavior of the blades quantitatively while oil flow patterns and Schlieren pictures provide qualitative results. The experimental results show that the strong pressure gradient near the stagnation point affects the velocity distribution of the jets. This non-uniformity produces additional aerodynamic losses. To take these effects into account for the Navier-Stokes calculation a multi-block grid was used to model the flow field in the ejection holes and in the mainstream. Thus, the experimental and numerical results show a good agreement.
Author (revised)

N93-29960# Centre National de la Recherche Scientifique, Ecully (France). Lab. de Mecanique des Fluides et d'Acoustique.
MODELING OF A TURBULENT FLOW IN THE PRESENCE OF DISCRETE PARIETAL COOLING JETS [MODELISATION D'UN ECOULEMENT TURBULENT EN PRESENCE DE JETS PARIETAUX DISCRETS DE REFROIDISSEMENT]
J. M. MAURICE, F. LEBOEUF, and P. KULISA *In* AGARD, Heat Transfer and Cooling in Gas Turbines 13 p (SEE N93-29926 11-07) Feb. 1993 In FRENCH
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

The high temperature level reached in the first turbine stages requires efficient blade cooling. Film cooling has proved its ability to protect the wall from the hot upstream flow. However, the jets strongly disturb the aerodynamic flow characteristics. As a consequence, the main objective of the designers is to get the best compromise between thermal strains and aerodynamic losses. A two-dimensional viscous flow model, with discrete jets and based on a boundary layer concept, was developed at Ecole Centrale de Lyon. The turbulence closure was first performed by a mixing length model. A low Reynolds number version of a k-epsilon model is presented. A space averaging method in the transverse direction is used; thereby the two-dimensional character of the computation is preserved, while the specific effects of the discrete jets are taking into account in the model. Comparisons with experimental results are given in the case of a row of jets, as injected through a turbulent boundary layer on a flat plate, near the injection orifice.
Author (revised)

N93-29961# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. fuer Antriebstechnik.
COUPLING OF 3D-NAVIER-STOKES EXTERNAL FLOW CALCULATIONS AND INTERNAL 3D-HEAT CONDUCTION CALCULATIONS FOR COOLED TURBINE BLADES
A. HESELHAUS, D. T. VOGEL, and H. KRAIN *In* AGARD, Heat Transfer and Cooling in Gas Turbines 9 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

The problem of cooled gas turbine blades is theoretically investigated. The presented code solves the 3D-Reynolds averaged-Navier-Stokes equations for the external passage flow and the 3D-heat conduction equation for the interior of the blade. Both calculation schemes are coupled without any modeling of the heat transfer boundary conditions at the blade surface. Calculations are presented for a thin hollow flat plate and a typical guide vane blade with a simple cooling channel configuration. Both geometries are cooled by prescribing fixed heat transfer boundary conditions at the inner boundaries. Additionally numerical results are compared to analytical data. The agreement is quite satisfactory.
Author (revised)

N93-29962# Politecnico di Milano, Milan (Italy). Dipt. di Energetica.
A NAVIER-STOKES SOLVER WITH DIFFERENT TURBULENCE MODELS APPLIED TO FILM-COOLED TURBINE CASCADES
F. BASSI, S. REBAY, M. SAVINI (National Center for Energetics and Propulsion, Peschiera Borromeo, Italy.), S. COLANTUONI (Alfa Romeo S.p.A., Naples, Italy.), and G. SANTORIELLO (Alfa Romeo S.p.A., Naples, Italy.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 16 p (SEE N93-29926 11-07) Feb. 1993
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The numerical simulation of transonic flows through film-cooled turbine cascades is described. The modelization of coolant injection was implemented in a computational code which solves either the laminar or the Reynolds-averaged Navier-Stokes equations in cascades. Turbulence effects are accounted for by means of the eddy viscosity concept. Two turbulence models were implemented in the code. The first is the Baldwin-Lomax algebraic model and the second is the two-equation k-omega model proposed by Wilcox. Both models were coupled with a Navier-Stokes solver in a simple, robust, and efficient way. The numerical solution of both the flow and the turbulence model equations is based on a cell centered finite volume scheme and on an explicit Runge-Kutta method for time integration. The code was applied to compute the transonic flow in a cascade of nozzle guide vanes (NGV's) developed by Alfa Romeo Avio S.p.A. The computations were performed both for a cascade of 'solid' vane profiles and for a cascade of 'cutted' vane profiles that allow coolant flow ejection through a slot on the pressure side near the trailing edge. The NGV cascade is still under testing and at present only the experimental data for the 'solid' NGV cascade are available for code validation. The computational results presented show that the proposed coupling of the k-omega model with the explicit Navier-Stokes solver does not seem to suffer from the stiffness problems often characterizing other two-equation turbulence models.
Author (revised)

N93-29963*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NAVIER-STOKES ANALYSIS OF THREE-DIMENSIONAL FLOW AND HEAT TRANSFER INSIDE TURBINE BLADE ROWS
C. HAH *In* AGARD, Heat Transfer and Cooling in Gas Turbines 11 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

A numerical method for solving the three-dimensional, Navier-Stokes equations for unsteady, viscous flow and heat transfer through multiple turbomachinery blade rows is presented.

The method solves the fully three-dimensional Navier-Stokes equations with an implicit scheme which is based on a control volume approach. A two-equation turbulence model with a low Reynolds number modification is employed. A third-order accurate upwinding scheme is used to approximate convection terms while a second order accurate central difference scheme is used for the discretization of viscous terms. A second-order accurate scheme is employed for the temporal discretization. The numerical method is applied to study the unsteady flow and heat transfer field of the High Pressure Fuel side Turbo-Pump (HPFTP) of the Space Shuttle Main Engine (SSME). The stage calculation is performed by coupling the stator and the rotor flow fields at each time step through an over-laid grid. Numerical results for the complete geometry with the vane trailing edge cutback are presented and compared with the available experimental data. Author (revised)

N93-29964# Sener Ingenieria y Sistemas S.A., Madrid (Spain).
COOLING PREDICTIONS IN TURBOFAN ENGINE COMPONENTS
A. MATESANZ, R. REBOLO, A. VIEDMA (Universidad Politecnica de Madrid, Spain.), and M. RODRIGUEZ (Universidad Politecnica de Madrid, Spain.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 7 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04
How the metal temperature measured in a convergent divergent nozzle and in a turbine exhaust diffuser of a turbofan engine can be predicted with reasonable approximation using the data available in the open literature is shown. It is shown how the simplified fluid dynamic equations with the appropriate experimental correlation allow the prediction of these results in other flight conditions than those tested. Author (revised)

N93-31741# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AGARD ENGINE DISC COOPERATIVE TEST PROGRAMME [RAPPORT SUR LE PROGRAMME D'ESSAIS COMMUN DES DISQUES MOTEUR (SUPPLEMENT)]
Apr. 1993 242 p
(AGARD-R-766-ADD; ISBN-92-835-0709-6; AD-A266817)
Copyright Avail: CASI HC A11/MF A03
Fatigue and crack growth tests of Ti-Al6-4V, IMI 685, and Ti-17 specimens under constant amplitude and under variable amplitude TURBISTAN loading sequences at room temperature are described. Five crack growth models are evaluated and compared against experimental data. Microstructure and fractography data for the tested materials are also presented. For individual titles, see N93-31742 through N93-31749.

N93-31742# National Aerospace Lab., Amsterdam (Netherlands).
FRACTOGRAPHIC AND MICROSTRUCTURAL ANALYSIS OF FATIGUE CRACK GROWTH IN TI-6AL-4V FAN DISC FORGINGS
R. J. H. WANHILL and C. E. W. LOOIJE *In* AGARD, AGARD Engine Disc Cooperative Test Programme 40 p (SEE N93-31741 12-07) Apr. 1993
(AGARD-R-766-ADD) Copyright Avail: CASI HC A03/MF A03
The constant amplitude and flight simulation (TURBISTAN) fatigue crack growth behavior of Ti6Al-4V fan disc forgings tested in the AGARD engine disc cooperative test program was investigated by fractographic and microstructural analysis. The crack growth curve shapes and fractographic characteristics were similar. Transitions in the fatigue crack growth curves correlated with a change from structure-sensitive to continuum-mode crack growth, primarily in the transformed and aged Beta grains, and decreased fracture surface roughness. The transitions were most probably caused by the maximum plane strain cyclic plastic zone sizes becoming equal to and exceeding the average platelet Alpha packet sizes. The significance of such transitions for prediction of fatigue crack growth and service failure analysis is discussed. Author

N93-31743# Defence Research Agency, Farnborough, Hampshire (England).
FRACTOGRAPHIC INVESTIGATION OF IMI 685 CRACK PROPAGATION SPECIMENS FOR SMP SC33
CHRIS WILKINSON and PAUL HEULER (Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn, Germany.) *In* AGARD, AGARD Engine Disc Cooperative Test Programme 4 p (SEE N93-31741 12-07) Apr. 1993
(AGARD-R-766-ADD) Copyright Avail: CASI HC A01/MF A03
Fracture surfaces from compact tension and corner crack specimens were examined for various complex waveforms. Features were related to the various stages of crack growth, as well as to the known response of the material. Author

N93-31744# Department of National Defence, Ottawa (Ontario). Quality Engineering Test Establishment.
MATERIAL CHARACTERIZATION AND FRACTOGRAPHIC EXAMINATION OF TI-17 FATIGUE CRACK GROWTH SPECIMENS FOR SMP SC33
MARKO YANISHEVSKY, BRYAN CORNWALL, and MARTIN ROTH *In* AGARD, AGARD Engine Disc Cooperative Test Programme 44 p (SEE N93-31741 12-07) Apr. 1993
(AGARD-R-766-ADD) Copyright Avail: CASI HC A03/MF A03
Material characterization and metallographic examination of the Ti-17 material tested as part of the Supplemental Program for Engine Disc Damage Tolerance Testing AGARD SC33 are included. As well, a complete fractographic examination is provided for the compact tension specimens tested under the six types of simple spectra load conditions and the four levels of load excursion damage level omission of the complex spectrum TURBISTAN, this latter spectrum representing NATO gas turbine engine missions used in fighter aircraft applications. Author (revised)

N93-31745# National Aerospace Lab., Amsterdam (Netherlands).
LOW CYCLE FATIGUE BEHAVIOUR OF TITANIUM DISC ALLOYS
C. E. W. LOOIJE *In* AGARD, AGARD Engine Disc Cooperative Test Programme 12 p (SEE N93-31741 12-07) Apr. 1993
(AGARD-R-766-ADD) Copyright Avail: CASI HC A03/MF A03
The low cycle fatigue behavior of the titanium alloys IMI 685, Ti-17 and Ti-6Al-4V tested in the AGARD Engine Disc Cooperative Test Program are described. Load controlled low cycle fatigue tests were carried out on smooth cylindrical and flat double edge notched specimens at room temperature. The test results were statistically analyzed and discussed. The tests showed that the differences in low cycle fatigue behavior between IMI 685 and Ti-6Al-4V are negligible and that Ti-17 has superior low cycle fatigue properties. Author (revised)

N93-31746# Institute for Aerospace Research, Ottawa (Ontario).
FATIGUE CRACK GROWTH RESULTS FOR TI-6AL-4V, IMI 685, AND TI-17
M. D. RAIZENNE *In* AGARD, AGARD Engine Disc Cooperative Test Programme 33 p (SEE N93-31741 12-07) Apr. 1993
(AGARD-R-766-ADD) Copyright Avail: CASI HC A03/MF A03
The fatigue crack growth results for the titanium alloys IMI 685, Ti-6Al-4V and Ti- 17 that were tested in the Supplemental phase of the AGARD SC.33 Engine Disc Cooperative Test Program are presented. The fatigue crack growth work was carried out under load control using compact tension and corner crack specimen geometries. Tests were conducted under the following loading conditions: constant amplitude ($R = 0.1$ and $R = 0.7$), constant amplitude ($R = 0$) with minor cycles, an $R = 1.7$ single overload sequence and the cold TURBISTAN variable amplitude sequence. The data is presented using a point to point or secant method. The constant amplitude and single overload data base was subsequently used by five participating laboratories to predict a series of 60 load cases using their respective crack growth prediction models. Author (revised)

N93-31747# Centre d'Essais Aeronautique Toulouse (France).
CRACK GROWTH PREDICTION MODELS
ERIC JANY and PAUL HEULER (Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn, Germany.) *In* AGARD, AGARD Engine Disc Cooperative Test Programme 4 p (SEE N93-31741 12-07) Apr. 1993
(AGARD-R-766-ADD) Copyright Avail: CASI HC A02/MF A03

Seven companies or laboratories initially entered the exercise: CEAT, FFA, GE, NASA, NLR, Pratt & Whitney, and Rolls-Royce. Two of them withdrew (GE, Pratt & Whitney). A short description of the models and some information on how the data base was handled in order to carry out the predictions are presented. A list of references on each model is given. Author (revised)

N94-10425# Alenia Aeronautica, Turin (Italy).
NUMERICAL SIMULATION OF THE FLOW THROUGH A SCRAMJET ENGINE
V. SELMIN *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 13 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

An inviscid numerical method was developed to simulate the flow through each component of a scramjet engine. Emphasis is on the effects due to non-ideal gas assumption and to H(sub 2)/air chemistry on the performance of air intakes and nozzles. Author (revised)

N94-11022# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
A RECOMMENDED METHODOLOGY FOR QUANTIFYING NDE/NDI BASED ON AIRCRAFT ENGINE EXPERIENCE [LE PROJET DE METHODOLOGIE POUR L'EVALUATION DU CONTROLE NON-DESTRUCTIF FONDE SUR L'EXPERIENCE ACQUISE SUR LES MOTEURS D'AVIONS]
Apr. 1993 97 p Lectures held in Ankara, Turkey, 26-27 Apr. 1993, in Lisbon, Portugal, 29-30 Apr. 1993, in Patras, Greece, 4 May 1993, and in Ottawa, Canada, 3-4 Jun. 1993
(AGARD-LS-190; ISBN-92-835-0707-X; AD-A266952; AD-A273386) Copyright Avail: CASI HC A05/MF A01

Methods to quantify nondestructive inspection (NDI) reliability and capability have been evolving for over twenty-five years. Initial attempts were qualitative rather than quantitative. With the advent of damage tolerance methodologies, it has become imperative to express more accurately probability of detection for a given inspection method and inspection system. This Lecture Series is aimed at providing a methodology to quantify probability of detection. This methodology includes, but is not limited to, design of experiments, specimen generation and maintenance, statistical analyses, data reduction and presentation, evaluation of inspection results in retirement for cause decisions, and the procedure required to establish a reliable probability based inspection for detecting anomalies in engine parts. The material to be presented is applicable to civil as well as military aircraft and turbine engine manufacturing and maintenance organizations. The lectures will examine the detection capabilities of fluorescent penetrant inspection, eddy current, ultrasonic, and magnetic particle inspection. This Lecture Series incorporates lessons learned in the design of experiments to validate nondestructive evaluation (NDE)/NDI systems and in the interpretation of the results of these experiments. Samples of specimens used in NDE/NDI reliability programs will be available for inspection by attendees. The Lecture Series also includes examples to help with the understanding of design of experiments and the statistical modeling for probability of detection analyses. This Lecture Series, sponsored by the Structures and Materials Panel of AGARD, was implemented by the Consultant and Exchange Program. Author (revised)

N94-24326*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MULTI-DISCIPLINARY COUPLING FOR INTEGRATED DESIGN OF PROPULSION SYSTEMS
C. C. CHAMIS and S. N. SINGHAL (Sverdrup Technology, Inc., Brook Park, OH.) *In* AGARD, Integrated Airframe Design Technology 12 p (SEE N94-24313 06-05) Dec. 1993
(AGARD-R-794) Copyright Avail: CASI HC A03/MF A02

Effective computational simulation procedures are described for modeling the inherent multi-disciplinary interactions for determining the true response of propulsion systems. Results are presented for propulsion system responses including multi-discipline coupling effects via (1) coupled multi-discipline tailoring, (2) an integrated system of multidisciplinary simulators, (3) coupled material-behavior/fabrication-process tailoring, (4) sensitivities using a probabilistic simulator, and (5) coupled materials/structures/fracture/probabilistic behavior simulator. The results show that the best designs can be determined if the analysis/tailoring methods account for the multi-disciplinary coupling effects. The coupling across disciplines can be used to develop an integrated interactive multi-discipline numerical propulsion system simulator. Author

N94-28018# Rolls-Royce Ltd., Bristol (England). Powerplant Technology.
INFLUENCE OF HEADWIND ON HOT GAS REINGESTION AND CONSIDERATION OF PRESSURE RATIO SCALING
C. J. PENROSE *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 9 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

A major concern affecting the operation of Advanced Short Take-Off and Vertical Landing (ASTOVL) aircraft close to the ground is ingestion by the aircraft intakes of engine hot exhaust gas. This hot gas reingestion (HGR) can produce loss of engine thrust and erode engine stability margins. A prime source of HGR is the flow occupying the region in the 'near' and 'mid' fields around the aircraft. The 'near-field' flow can be controlled by aircraft-mounted anti-HGR devices but these are likely to be less effective in containing the mid-field flow which is greatly influenced by headwind. Near and mid-field ingestion on Harrier-type configurations has, for many years, been studied by means of model-scale experiments. In most cases in the United Kingdom, the experiments have been set up observing scaling procedures which include consideration of the buoyant action of the hot gas and imply tests at low jet velocities with dynamic head similarity maintained. It can be argued that low velocities may not be appropriate for currently-conceived ASTOVL aircraft employing high pressure-ratio supersonic exhausts, and it may be more appropriate to test at full-scale nozzle pressure ratios. This paper reviews the effects of headwind on HGR for Harrier-type configurations during landing maneuvers with tests carried out both at low jet velocities consistent with buoyancy scaling (NPR(sub F) = 1. 07) and at velocities representative of full-scale nozzle pressure ratios (NPR(sub f) = 2.46). The HGR results are examined in relation to expectations of the forward-flowing gas cloud height and penetration distance for the engine exhaust streams while under the influence of headwinds. Author (revised)

N94-28019# Rolls-Royce Ltd., Bristol (England). Powerplant Technology.
UNSTEADY ASPECTS OF HOT GAS REINGESTION AND STATISTICAL ANALYSIS
R. BEASLEY *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 6 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

The ingestion of engine exhaust gases into an aircraft intake during jet-lift Advanced Short Take-off and Vertical Lift (ASTOVL) aircraft operation close to the ground is an area of considerable concern and has been the subject of much experimental study. The recirculatory flows follow complex paths which are strongly influenced by interference with the ground, aircraft structures, adjacent jet streams, and by the action of an oncoming headwind. The flows are turbulent at a large scale and unsteady with 'streaks' of hot gas entering the intake in a random manner. This Hot Gas Reingestion (HGR) can erode engine stability margins in a region of aircraft operation where reliable engine performance is critical. To ensure engine stability, sophisticated analysis techniques are required to enable prediction of worst-case destabilizing temperature distortion levels for chosen aircraft/engine combination. This paper describes the development and application of statistical analysis techniques designed to examine results of model experiments. These techniques enable quantitative conclusions to be reached as an extension to qualitative examination of trends from observed data. Due to the nature of the flow and distortion parameter, observed HGR data distributions are frequently not normal (Gaussian), and standard statistical techniques cannot be used. Author (revised)

N94-28037# Karlsruhe Univ. (Germany).
ANALYSIS OF COOLING JETS NEAR THE LEADING EDGE OF TURBINE BLADES
E. BENZ, S. WITTIG, A. BEECK (ABB Power Generation, Inc., Baden, Switzerland.), and L. FOTTNER (Universitaet der Bundeswehr Muenchen, Neubiberg, Germany.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 12 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A03/MF A04
Film-cooling air ejection affects the aerodynamics of turbine blades by the mixing of the coolant with the mainstream as well as by the interaction between the jet and the boundary layer. In the present paper, these effects are studied experimentally and numerically. The results show that the flow in the coolant channel is strongly affected by the main flow around the blade, leading to significant deflection of the coolant air jets. To account for these interactions between the cooling jet and the main flow in the numerical predictions, a multi-block technique is applied. With this technique very complex but structured geometries can be modelled by simply attaching grids of the different sub-domains. For the present investigations, these sub-domains are the two coolant channels at the leading edge and the main flow around the blade. For adaption to the curved geometry of such a turbine blade, a non-orthogonal body fitted grid is used for solving the time average two- or three-dimensional compressible Navier-Stokes equations by a finite volume method. The turbulence is taken into account by the standard k-epsilon model. For discretization of the convective terms the Monotonized-Linear-Upwind scheme (MLU) is used. The pressure-velocity coupling is achieved by the SIMPLEC-algorithm for compressible flows. The calculated results are compared with experimental investigation performed with a L2F-system at a large scaled turbine blade. Three typical blowing ratios are presented. Due to the simultaneous calculation of the coolant flow and the main flow, good agreement was obtained. Author

N94-29254# Technische Hochschule, Darmstadt (Germany). Inst. fuer Energie- und Kraftwerkstechnik.
NUMERICAL MODELLING OF TURBINE COMBUSTION CHAMBERS
S. MAIDHOF and J. JANICKA *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 10 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04
This paper focuses on the calculation of the flow and scalar fields of axisymmetric gas turbine combustion chambers with non-premixed combustion. Modelling of the turbulent swirling flow is carried out both by viscosity and Reynolds stress closure. It is our intention to specify the shortcomings as well as the potential of the different schemes with regard to prediction capabilities, numerical performance, and economic worth. The various aspects of modelling are discussed. A short description of the governing transport equations as well as the turbulence closure is given. An equilibrium chemistry model is compared to a laminar flamelet model, both schemes applied in conjunction with a probability density formulation for scalar properties. Numerical results of velocities and temperature in model gas turbine combustion chambers are compared with experimental results. Probable reasons for deviations are deduced and some prospects for possible future development of numerical simulation of gas turbine combustion are given. Author (revised)

N94-29255# Alfa Romeo S.p.A., Naples (Italy). Research and Development Dept.
NUMERICAL SIMULATION OF AEROTHERMAL CHARACTERISTICS IN GAS TURBINE COMBUSTORS WITH COMPLEX GEOMETRIES
P. DIMARTINO, G. CINQUE, and C. PADUANO *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 14 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04
A method is presented for calculating steady three-dimensional two-phase turbulent reactive flows with curved irregular boundaries. The gas phase equations are solved in an Eulerian frame of reference by a numerical technique based on the finite volume approach, while the equations describing droplet motion, evaporation, and burning are treated in a Lagrangian frame of reference. Turbulent transport is described by the standard k-epsilon model. The combustion model utilizes a conserved scalar formulation and an assumed shape probability density function to account for chemistry-turbulence interaction. The numerical scheme employs structured non-orthogonal grids, a node-centered variable arrangement, and Cartesian velocity components. A special interpolation procedure is used to avoid checkerboard oscillations due to pressure-velocity coupling, and a low diffusive and bounded scheme is introduced to approximate the convective terms in the transport equations. The capabilities of the numerical procedure are demonstrated by simulating an annular combustion chamber for which experimental results were available. The agreement between calculation and experiments ranges from fair to good. Author (revised)

N94-29256# General Motors Corp., Indianapolis, IN. Gas Turbine Div.
APPLICATION OF CFD IN COMBUSTOR DESIGN TECHNOLOGY
HUKAM C. MONGIA *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 18 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04
Multidimensional computational combustion dynamics has been used over the last twenty years to provide improved insight during gas turbine combustor design and development processes. The empirical/analytical combustor design methodology that was first demonstrated under the Army sponsored Combustor Design Criteria Validation program conducted during 1974-1978 has been used in the design and demonstration of 15 advanced rig combustors, four technology demonstrator engine combustors, three engine combustors, and one small turbine augmentor. Recognizing the limitations of turbulent combustion models, numerics, and the assumptions required to fully specify the boundary conditions for practical gas turbine combustion systems, a new technique that combines state-of-the-art turbulent combustion models with 'consistent' macro-volume expressions ('hybrid combustor modelling') was proposed. This hybrid modeling approach has been calibrated with combustors that include diffusion flame, lean premix/prevaporized, or rich-lean types of combustion processes. The hybrid modeling technique gives good 'quantitative' agreement with measured data on gaseous emissions, smoke, combustion efficiency, lean blowout fuel-air ratio, pattern factor, liner wall temperature levels, and gradients of a number of combustors. Author (revised)

N94-29257# Pratt and Whitney Aircraft of Canada Ltd., Mississauga (Ontario).
RECENT CFD APPLICATIONS IN SMALL GAS TURBINE COMBUSTION SYSTEMS DEVELOPMENT
T. C. J. HU and L. A. PROCIW *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 12 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04
A typical small gas turbine combustor is modelled using CFD, and the numerical results are compared with laser doppler velocimetry (LDV) measured data. The predicted flow characteristics are in excellent agreement with the measurements. Some aspects of CFD application in combustor design are discussed. CFD can be used in the following ways: as a tool in studying the flowfield development; in the optimization of location, size, and quantity of flow devices; in monitoring flow performance; and in correlating important design parameters. Use of CFD can significantly reduce the lapse time and the development cost of gas turbine combustors. Author

N94-29258# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
AEROTHERMOCHEMICAL CALCULATIONS IN AFTERBURNERS [CALCULS AEROTHERMOCHIMIQUES DANS LES FOYERS DE RECHAUFFE]
C. DEJEU, J. L. SCHULTZ, and S. MEUNIER *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 8 p (SEE N94-29246 08-25) Sep. 1993 In FRENCH Original contains color illustrations
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04
The detailed study of the aerodynamics and the thermodynamics of systems is an important part in the process of dimensioning and optimizing the afterburning chambers of modern turbojets. In this context, the article presents two examples of geometries and

recent results drawn from concrete cases. The aerothermochemical code which was used was developed by ONERA within the framework of the Cooperative Action for Combustion Chambers (A3C). It is based on a volumes type technique finished with a structured three-dimensional mesh adapted to the walls. The model of combustion used of the generalized type 'Eddy Break Up' is the subject of a more detailed presentation. Author (revised)

N94-29263# General Electric Co., Cincinnati, OH. Advanced Engine Combustor Aero Design.
FUEL INJECTOR DESIGN FOR HIGH TEMPERATURE AIRCRAFT ENGINE
R. W. STICKLES, W. J. DODDS, T. R. KOBLISH, J. SAGER, and S. CLOUSER *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 12 p (SEE N94-29246 08-25) Sep. 1993
(Contract(s)/Grant(s): N00140-87-C-6321)
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

The objective of the Innovative High Temperature Aircraft Engine Fuel Nozzle Program was to design and evaluate a nozzle capable of operating at a combustor inlet air temperature of 1600 F (1144 K) and a fuel temperature of 350 F (450 K). The nozzle was designed to meet the same performance requirements and fit within the size envelope of a current production dual orifice fuel nozzle. The design approach was to use improved thermal protection and fuel passage geometry in combination with fuel passage surface treatment to minimize coking at these extreme fuel and air temperatures. Heat transfer models of several fuel injector concepts were used to optimize the thermal protection, while sample tube coking tests were run to evaluate the effect of surface finish, coatings and tube material on the coking rate. Based on heat transfer analysis, additional air gaps, reduced fuel passage flow area and use of ceramic tip components reduced local fuel wetted wall temperatures by more than 200 F (100 K) when compared to a current production fuel nozzle. Sample tube coking test results showed the importance of surface finish on the fuel coking rate. Therefore, a one micro-inch (0.025 micron) roughness was specified for all fuel passage surfaces. A novel flow divider valve in the tip was also employed to reduce weight, allow room for additional thermal protection, and provide back pressure to reduce the risk of fuel vaporization. The fuel nozzle was fabricated and evaluated in a series of high temperature coking tests. Initial results of these tests indicate that thermal protection and surface treatments were partially successful in preventing nozzle fouling, but additional refinement of the internal flowpath is needed to prevent buildup of coke particles that partially blocked the spin slots which meter the nozzle fuel flow. Author

N94-29264# Pratt and Whitney Aircraft of Canada Ltd., Mississauga (Ontario).
DESIGN ASPECTS IN SMALL AIRCRAFT GAS TURBINE FUEL INJECTORS
K. MCCALDON, L. A. PROCIW, and P. SAMPATH *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 10 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

The causes of fuel injector spray deterioration and the effects of this deterioration on engine durability and performance are discussed. Small aircraft gas turbine fuel injectors present special design challenges due to low fuel flow rates involved and the physical size limitations. The principal fuel injector performance requirements are discussed in relation to their effect on the hydraulic, aerodynamic, and thermal design of aerating fuel injectors. Author

N94-29267# Leeds Univ. (England). Dept. of Fuel and Energy.
ULTRA LOW NO(X) ULTRA LEAN GAS TURBINE PRIMARY ZONES WITH LIQUID FUELS
G. E. ANDREWS, H. S. ALKABIE, U. S. ABDULHUSSAIN, and M. ABDULAZIZ *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 14 p (SEE N94-29246 08-25) Sep. 1993 Sponsored in part by Science Research Council
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

Three low NOx gas turbine combustor design concepts, Jet Mix, Grid Mix and radial swirlers, which have been demonstrated to give very low NOx emissions using gaseous fuels have been successfully tested on liquid fuels and low NOx emissions demonstrated. The Jet Mix was shown to have low NOx emissions at atmospheric pressure and has been tested at pressure, with similar low NOx results. Kerosene performance and emissions was very similar to that for propane as the fuel. The scale up of the Jet Mix was found to be possible without increasing the NOx emissions greatly and is a preferable design option to the use of large numbers of smaller Jet Mix modules. Sector tests at pressure showed the Jet Mix design produced emission reductions close to the best of the NASA clean combustor results. The Grid Mix low NOx design was shown to be capable of low NOx performance using kerosene. There was a much wider flame stability than for the Jet Mix design and lower NOx emissions were demonstrated. The radial swirler with vane passage of 76mm wall fuel injection was shown to have ultra low NOx emissions with liquid fuels, only slightly higher than for gaseous fuels. For a high air flow radial swirler it was found that central kerosene injection gave lower NOx emissions than for gaseous fuels and had the potential to yield a NOx EI of below 10 at simulated take off conditions.
Author

N94-29269# United Technologies Research Center, East Hartford, CT. Aerothermal Technology/Chemical Sciences.
EVALUATION OF THE TRANSIENT OPERATION OF ADVANCED GAS TURBINE COMBUSTORS
T. J. ROSFJORD and J. M. COHEN *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 10 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by Pratt and Whitney Aircraft
(Contract(s)/Grant(s): N00140-87-C-9902)
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

A unique test capability has been defined and used at the United Technologies Research Center to evaluate the transient response of advanced gas turbine combustors. This UTC Transient Combustion Facility offers the opportunity to achieve pre-defined time variations of the air and fuel flow rates and air temperature delivered to a combustor model. This capability can be used for model scales ranging from multi-nozzle combustor sectors to smaller setups focusing on one component or process. A dedicated control computer aids in establishing time profiles for the input parameters and automatically executing the transient test. Among its applications, the facility has been used to study the occurrence of in-nozzle fuel vaporization during Bodie cycles and to assess the tolerance of a fuel-staged combustor to rapid fuel redistribution. Author

N94-29270# Fiat Aviazione S.p.A., Turin (Italy). Direzione Progettazione.
TECHNOLOGY RIGS: A TOOL FOR AFTERBURNER DEVELOPMENT
G. RICCARDI, A. TASSELLI, and A. TROVATI *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 17 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

To develop a component of an advanced aircraft engine, heavy experimental activities are necessary. To avoid very long and expensive test campaigns on development engines, tests on the so-called technology rigs are fundamental. Particularly in the case of combustion components, whose analytical simulations by means of computer code are still not completely satisfactory and where very high gas temperatures may cause important problems of mechanical integrity, it is essential to check the behavior of the component on the rig before testing on the engine. This paper gives an overview of the test rigs which are used by FiatAvio in the development of the afterburner system for an advanced fighter aircraft engine. The tests which are carried out on these rigs are described and some of the most important results are reported, discussing the benefit they have given to the engine development. Even if this paper obviously does not cover all the results obtained from rig tests over years of engine development, the few examples reported clearly show the importance of these rigs and confirm that the financial outlay to build and update the rigs, test plants and models is worthwhile. Author

07 AIRCRAFT PROPULSION AND POWER

N94-29291# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Lab.
RESEARCH AND DEVELOPMENT OF RAM/SCRAMJETS AND TURBORAMJETS IN RUSSIA [LA RECHERCHE ET LE DEVELOPPEMENT DES STATOREACTEURS, DES STATOREACTEURS A COMBUSTION SUPERSONIQUE ET DES TURBOSTATOREACTEURS EN RUSSIE]
Dec. 1993 230 p Lecture series held in Laurel, MD, 1-2 Dec. 1993, in Cologen, Germany, 13-14 Jan. 1994, and in Paris, France, 17-18 Jan. 1994
(AD-A275588; AGARD-LS-194; ISBN-92-835-0732-0) Copyright Avail: CASI HC A11/MF A03

Russia has a long tradition of achievement in ramjet research and development. The need for new and effective products has led to the establishment of ramjet research as a priority in Russian research and development. This Lecture Series will present and discuss the scientific problems associated with the development of ramjets/scramjets and turboramjets. Some specific aspects of liquid/solid ramjet development, the concepts of LH2 high efficiency RAM combustors, the results of full scale turboramjet testing, scramjet or CFD analyses, and ground flight tests will be studied. This Lecture Series, endorsed by the Propulsion and Energetics Panel of AGARD, has been implemented by the Consultant and Exchange program. For individual titles, see N94-29292 through N94-29301.

N94-29292# Central Inst. of Aviation Motors, Moscow (Russia).
INTRODUCTION AND OVERVIEW OF RESEARCH AND DEVELOPMENT OF SOLID PROPELLANT RAMROCKETS, LIQUID FUEL RAMJETS AND EXPERIMENTAL HYDROGEN RAM COMBUSTORS
V. SOSOUNOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 19 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

Ramjets, turboramjets, and scramjets have been studied intensively as possible propulsion systems for missiles, high velocity planes, and aerospace planes, which would use this type of propulsion during the atmospheric acceleration phase. All of these propulsion system configurations have a degree of commonality: ram ducts. This fact is discussed in this section of the Lecture Series. CASI

N94-29293# Central Inst. of Aviation Motors, Moscow (Russia).
TURBORAMJET ENGINES: TYPES AND PERFORMANCES
M. M. TSKHOVREBOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 22 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

In this report on turboramjet engines, some of the properties of variable cycle propulsion plants based on a combination of ramjet and various turbine-type engines are considered. Various measures of engine thrust performance vs. Mach number are represented. Turboramjet engines (TRE) are classified according to their manner of energy transfer to the ramjet parts. The defining principles of essential TRE propulsion plant working parameters are considered. TRE's with various levels of thrust performance are presented. An effectiveness comparison of various combined propulsion plants for future hypersonic transport planes and a TSTO first stage with LH2 fuel is given. A preference is shown for the turboramjet engine as a universal multimode propulsion plant. The optimization of operating modes in response to changing conditicns is adopted as an approach to governing the operation of a combined engine working process. Author (revised)

N94-29294# Central Inst. of Aviation Motors, Moscow (Russia).
RESEARCH AND DEVELOPMENT OF RAMJETS/RAMROCKETS. PART 1: INTEGRAL SOLID PROPELLANT RAMROCKETS
V. SOSOUNOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 31 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

Solid propellant ramrockets (SPRR) combine the exclusive operational advantages of solid rockets with the higher fuel efficiency of air breathing engines. The specific feature of an SPRR which differs from a liquid fuel ramjet is the arrangement of the ram combustor in which the products of the primary burning of the solid propellant inside the gas generator are injected through nozzles and reburned. The second feature of the SPRR combustion process is that the gas by-products of primary gas generator are reburned in the ram combustor as turbulent or quasi-turbulent gas flames. Usually there is no need for special flameholders. These special features can lead to some peculiarities in the inserted booster case and to rather complicated gasified fuel supply devices. The third special (negative) feature of SPRR is the constant or programmed fuel supply rate during the flight. Hence, the problem of SPRR fuel flow rate control arises. This lecture discusses the following topics: integration of SPRR with a booster rocket engine; the energy capabilities of different ramjet solid propellants and their application; the effectiveness of secondary fuel combustion in the ram combustor; model and full scaled ramrocket ground testing; and fuel flow rate control in ramrockets. Author (revised)

N94-29295# Central Inst. of Aviation Motors, Moscow (Russia).
SOME PROBLEMS OF SCRAMJET PROPULSION FOR AEROSPACE PLANES. PART 1: SCRAMJET: AIMS AND FEATURES
A. ROUDAKOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 20 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

This lecture addresses problems of scramjet propulsion for single-stage aerospace planes. The aerospace plane main objective is acceleration of some payload up to orbital speed. It defines a requirement for the propulsion system to be frugal in the wide flight speed range under conditions of propulsion mass limitation and thrust compared with flight vehicle weight. In accordance with modern estimations, real hydrogen fuel scramjet specific impulse may be several times more than that of a rocket engine in the wide flight speed range, from Mf = 5...6 up to Mf = 15...20. But hydrogen scramjet propulsion requires significant air ram connected with high heating of vehicle structure, large hydrogen tanks (and vehicle), and special forms of the flight vehicle. As a result the scramjet advantage, as well as any other air breathing engine advantage, over the modern liquid rocket engines is not doubtless. Nevertheless scramjets can provide good efficiency in aerospace planes if each scramjet element and units are developed very carefully and have high performances. In another case, scramjet may lose competition with liquid rocket engines and a full scale scramjet will be never created. Theoretical and experimental investigations, ground and flight model tests have demonstrated the possibility of supersonic combustion ramjet for hypersonic flights. But we must carry out serious investigations to obtain high efficiency of scramjet elements and scramjet propulsion as a whole to be sure of scramjet success in aerospace plane competition with liquid rocket engine. Author (revised)

N94-29296# Central Inst. of Aviation Motors, Moscow (Russia).
SCRAMJET CFD METHODS AND ANALYSIS. PART 1: SCRAMJET CFD METHODS. NUMERICAL SIMULATION OF THE FLOW IN SCRAMJET DUCT
V. KOPCHENOV, K. LOMKOV, L. MILLER, V. KRJUKOV, I. RULEV, V. VINOGRADOV, V. STEPANOV, N. ZACHAROV, R. TAGUIROV, and M. AUKIN *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 20 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

The computer analysis of scramjet flow became of great importance because of the limited possibilities of ground tests and difficulties of measurements in high speed/enthalpy flows. This fact is a powerful stimulus in CFD development. A short description and examples of applications of the mathematical model for scramjet duct flow developed in CIAM are presented in this paper. Derived from text

N94-29297# Central Inst. of Aviation Motors, Moscow (Russia).
RESEARCH AND DEVELOPMENT OF RAMJETS/RAMROCKETS. PART 2: INTEGRAL LIQUID FUEL RAMJETS
V. SOSOUNOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 23 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

Integral liquid fuel ramjets (LFRJ) have some specific features influencing their arrangement and construction. Among such features are: a larger size and working duration than solid propellant ramjets (SPRR), the necessity of fuel manifolds and flameholders, the wall cooling system arrangement in the combustion chamber, and the possibility of fuel flow and nozzle position control during flight on different speed/altitude trajectories. This lecture will discuss some items concerning the mentioned LFRJ features: the integration of ram combustor and booster; duct flow instability during the ejection of booster case; fuel supply device and effective combustion in ramjet; and adaptive control of ramjet on different flight trajectories. Author (revised)

N94-29298# Central Inst. of Aviation Motors, Moscow (Russia).
RESEARCH AND DEVELOPMENT OF RAMJETS/RAMROCKETS. PART 3: THE STUDY OF GASEOUS HYDROGEN RAM COMBUSTORS
V. A. SOSOUNOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 6 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A02/MF A03

The peculiarities of H2 ramjet turboramjet high efficiency ram combustors are discussed which include some special topics such as: flame stabilization behind the nozzle edge; increase of the number of nozzles and ram combustor length reduction; separate combustion without mixing of flames; uniform spread of fuel and air in chamber section; the experiment on model burner series; and methods of effective H2 combustion in a short combustor. Author (revised)

N94-29299# Central Inst. of Aviation Motors, Moscow (Russia).
CIAM EXPERIMENTAL TURBORAMJETS
M. M. TSKHOVREBOV, V. I. SOLONIN, and P. A. K. ADJARDOUZOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 23 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

In this report, some results of the TRE operating process including those performed on specially developed demonstrator engines are considered. Essential technical requirements and design features of the experimental TRE designed and developed at CIAM for investigatory study on a test bench are shown. Test facilities for experimental investigations of TRE in 'connected tube' manner and experimental work technology features are presented. Some results of the CIAM TRE experimental study included engine parameters on changing to ramjet operation mode variation. Working parameters in the windmilling (ramjet) mode of operation, and flow characteristics in the afterburner-ramjet combustion chamber are shown. A TRE based on TF parts characteristics matching on changing to ramjet operation mode and engine working parameter variations when going to windmilling in the ramjet mode are discussed. Author (revised)

N94-29300# Central Inst. of Aviation Motors, Moscow (Russia).
SCRAMJET CFD METHODS AND ANALYSIS. PART 2: SCRAMJET CFD ANALYSIS. NUMERICAL SIMULATION OF SUPERSONIC MIXING AND COMBUSTION APPLIED TO SCRAMJET COMBUSTOR
V. KOPCHENOV, K. LOMKOV, S. ZAITSEV, and I. BORISOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 30 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

A short description of a mathematical model developed in CIAM for numerical simulation of supersonic mixing and combustion, which permits the analysis of the three-dimensional effects, is presented. Some aspects of mixing and combustion enhancement will also be considered on the base of CIAM experience. Derived from text

N94-29301# Central Inst. of Aviation Motors, Moscow (Russia).
SOME PROBLEMS OF SCRAMJET PROPULSION FOR AEROSPACE PLANES. PART 2: SCRAMJET: DEVELOPMENT AND TEST PROBLEMS
A. ROUDAKOV *In* AGARD, Research and Development of Ram/Scramjets and Turboramjets in Russia 26 p (SEE N94-29291 08-07) Dec. 1993
(AGARD-LS-194) Copyright Avail: CASI HC A03/MF A03

The topics covered include the following: SCRAMJET development strategy; subscale model SCRAMJET flight tests; hypersonic flying laboratory and experimental double mode SCRAMJET; SCRAMJET operation in flight conditions; and experimental dual model SCRAMJET parameters. Derived from text

N94-33874# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
GUIDE TO THE MEASUREMENT OF THE TRANSIENT PERFORMANCE OF AIRCRAFT TURBINE ENGINES AND COMPONENTS [GUIDE POUR LA MESURE DES PERFORMANCES EN TRANSITOIRE DES TURBOMACHINES AERONAUTIQUES ET DE LEURS COMPOSANTS]
EARL H. DUDGEON, ed. (National Research Council of Canada, Ottawa, Ontario.) Mar. 1994 404 p
(AD-280272; AGARD-AR-320; ISBN-92-835-0739-8) Copyright Avail: CASI HC A18/MF A04

This report provides a guide for the measurement of transient aerothermodynamic performance parameters of aircraft gas turbine engines or components for engine developers, test agencies, certifying authorities, and operators of overhaul facilities and aircraft. It may be treated as an extension of AGARD Advisory Reports AR-245 and AR-248. It includes discussion of recommended procedures for the transient measurement of pressures, temperatures, flows, component geometry including rotational speed and clearances, thrust, torque, and the use of the engine control system for transient parameter measures. Typical examples are presented. A section on data acquisition and processing is included. Higher frequency dynamic measurements are excluded. Two examples, the measurement of compressor ratio and air flow at surge and a measurement of engine acceleration time are discussed in detail. This Advisory Report was prepared at the request of the Propulsion and Energetics Panel of AGARD. Author

N94-34431# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
TECHNOLOGY REQUIREMENTS FOR SMALL GAS TURBINES [LES TECHNOLOGIES POUR LES PETITES TURBINES A GAS]
Mar. 1994 474 p In ENGLISH and FRENCH The 82nd Symposium was held in Montreal, Quebec, 4-8 Oct. 1993 Original contains color illustrations
(AD-280274; AGARD-CP-537; ISBN-92-835-0738-X) Copyright Avail: CASI HC A20/MF A04

These Conference Proceedings contain the papers presented at the Propulsion and Energetics Panel 182nd Symposium on Technology Requirements for Small Turbines which was held from 4th-8th October 1993, in Montreal, Canada. The Technical Evaluation Report and the Technology Overview Address are included at the beginning, and discussions follow most papers. The Symposium was arranged in the following Sessions: Technology Overview; Turboshaft Engines; Turbofan Engines; Auxiliary Power Units; Compressors 1 - Centrifugal; Compressors 2 - Axial; Combustors; Turbines 1 - Axial; Turbines 2 - Radial; Structures and Materials; and Bearings. For individual titles, see N94-34432 through N94-34466.

N94-34432# Ministry of Defence, London (England). Directorate of Future Air Systems.
OPERATIONAL REQUIREMENTS FOR HELICOPTER ENGINES FOR UK SERVICES
M. D. PARAMOUR and P. G. JENNINGS *In* AGARD, Technology Requirements for Small Gas Turbines 9 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

This paper reviews the requirements of the United Kingdom Armed Services for helicopter engines and the technology

developments that will be necessary to meet these requirements. The work that is being done in the UK to ensure that this technology is demonstrated in a timely manner is also examined. Reductions in defense budgets will have a considerable effect on the requirements, and the paper also addresses the effect such reductions will have on future technology. Whilst there continues to be a divergence between naval and land-based requirements, overriding importance is now being given by all operators to cost of ownership issues. The need to reduce the cost of ownership will therefore need to influence all the research and technology demonstration programs on which future engines will rely.
Author

N94-34434# Technische Univ., Munich (Germany).
MTR390, THE NEW GENERATION TURBOSHAFT ENGINE
AUGUST SPIRKL *In* AGARD, Technology Requirements for Small Gas Turbines 8 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04
In June 1993, the MTR390 has completed all its important certification tests. This marks a major step in the development and qualification program of this engine which was selected to power the new German/French anti-tank, support and attack helicopter, the EUROCOPTER TIGER and GERFAUT. The MTR390 is a new turboshaft engine in the 1000KW (1300shp) range being jointly developed by three of the largest European aero engine companies: MTU in Germany, TURBOMECA in France, and ROLLS-ROYCE in Great Britain. The joint company MTR GmbH which is registered in Germany, acts as contractor for the German and French governments. MTR directs and coordinates the development, production, marketing, sales, and customer support of the MTR390 engine for the Franco-German helicopters and other potential applications. The three companies have been working together for more than 25 years on several programs like Adour, Larzac, RB199, EJ200, RTM322,.... The declared goal of the MTR partner companies is to create an engine that will not only suit the TIGER/GERFAUT program but will also compete in the military and civil market for the next 20 to 30 years. Author

N94-34435# Alfa Romeo S.p.A., Naples (Italy). Research and Development.
AEROTHERMAL DESIGN OF 1600 K TET CORE ENGINE HOT-SECTION COMPONENTS FOR HIGH-TECHNOLOGY COMPACT PROPULSION SYSTEMS
S. COLANTUONI, A. COLELLE, G. SANTORIELLO, L. CIRILLO, and C. IOSSA *In* AGARD, Technology Requirements for Small Gas Turbines 24 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04
The paper describes the aerodynamic and thermal design for the hot-section core engine components, i.e. the combustor and the HP turbine, for an application related to a propulsion system of 1000 kW class. The annular reverse-flow flame-tube is very compact in length and radial dimensions. The high pressure gas-generator turbine is an axial-flow single stage, aerodynamically high loaded, and has nozzle vanes as well as rotor blades cooled by impingement, film cooling and forced enhanced convection techniques. Furthermore the core engine hot section rig has been designed to allow, through an extensive experimental program, the verification of the performances, and to study the impact of the cooling systems on the thermo-mechanical behavior of the components. Author

N94-34436# Pisa Univ. (Italy). Dipt. di Energetica.
NON-POLLUTING GAS TURBINE AS A RESULT OF SELF-HEATING WORKING FLUID IN A CLOSED CIRCUIT
DINO DINI *In* AGARD, Technology Requirements for Small Gas Turbines 5 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A01/MF A04
Design and experimental results of a small turboshaft operating with self-heating working fluid are presented here. The working fluid is water steam produced through H2, O2, H2O combustion, water being injected gradually on the H2/O2 stoichiometric combustion products. High pressure (50 divided by 70 bar) and high temperature (1000 divided by 1500 K) water steam is involved, respectively, because of mechanically driven pumps for liquid hydrogen and oxygen and water, and because their combustion. So, water steam is operating the turboshaft until vacuum pressure condenses in an aircondenser after a previous heat exchange, in a closed cycle. Only a part of the steam latent heat is going to the environment. An overall thermodynamic design, and a more detailed combustor design, are presented, showing high cycle efficiency and validity for such a non-polluting turboshaft. Experimental results of the H2/O2/H2O combustor are reported. Applications are suggested for small power entertainment airplanes, rescue helicopters, and non-polluting airport ground vehicles.
Author

N94-34437*# Army Aviation Research and Development Command, Cleveland, OH. Vehicle Propulsion Directorate.
ANALYSIS OF RIG TEST DATA FOR AN AXIAL/CENTRIFUGAL COMPRESSOR IN THE 12 KG/SEC
A. K. OWEN *In* AGARD, Technology Requirements for Small Gas Turbines 30 p (SEE N94-34431 10-07) Mar. 1994 Sponsored by NASA. Lewis Research Center
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04
Extensive testing was done on a T55-L-712 turboshaft engine compressor in a compressor test rig at TEXTRON/Lycoming. These rig tests will be followed by a series of engine tests to occur at the NASA Lewis Research Center beginning in the last quarter of 1993. The goals of the rig testing were: (1) map the steady state compressor operation from 20 percent to 100 percent design speed, (2) quantify the effects of compressor bleed on the operation of the compressor, and (3) explore and measure the operation of the compressor in the flow ranges 'beyond' the normal compressor stall line. Instrumentation consisted of 497 steady state pressure sensors, 153 temperature sensors and 34 high response transducers for transient analysis in the pre- and post-stall operating regime. These measurements allow for generation of detailed stage characteristics as well as overall mapping. Transient data is being analyzed for the existence of modal disturbances at the front face of the compression system ('stall precursors'). This paper presents some preliminary results of the ongoing analysis and a description of the current and future program plans. It will primarily address the unsteady events at the front face of the compression system that occur as the system transitions from steady state to unsteady (stall/surge) operation. Author

N94-34438# Williams International, Walled Lake, MI.
EXPENDABLE GAS TURBINE ENGINE TECHNOLOGY ADVANCES
G. S. CRUZEN *In* AGARD, Technology Requirements for Small Gas Turbines 8 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04
New materials and component technologies are undergoing feasibility assessment in expendable gas turbine demonstrator engines. The new technologies, developed under the Integrated High Performance Turbine Engine Technologies (IHPTET) and other initiatives, address the need for improved engine performance, lower cost, and lighter weight. Engine and rig tests conducted on high temperature composite turbine components, fuel-lubricated ceramic bearings, low cost, light weight organic composite structures, and a novel low cost cooled turbine rotor concept are described in this paper. Also, additional development requirements for transitioning these technologies to production applications are defined. Author

N94-34439# BMW Rolls-Royce AeroEngines G.m.b.H., Lohholf (Germany).
EXPERIMENTAL INVESTIGATION AND PERFORMANCE ANALYSIS OF THE TURBOJET ENGINE T117
GERNOT EISENLOHR and PETER HOECHST *In* AGARD, Technology Requirements for Small Gas Turbines 7 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04
The T117 Turbojet Engine (formerly KHD T117) is a single shaft light weight turbojet of the 1000 N thrust class. It was especially developed to fit into the reconnaissance drone Canadair CL 289. The demand for smallest possible size of the compressor to fit the constraints of outer diameter and axial length of the complete engine showed early that only a single stage radial compressor would be applicable. The compression system of this turbojet is described in some detail. The performance maps of the compressor at the test-stand without and with turbojet inlet system are shown. Calculated and measured operating lines in the performance maps show good agreement. Tests with several production engines to establish the compressor performance map are shown and they confirm the compressor map with turbojet

inlet system at the compressor test-stand. Enough surge margin for the jet-engine is demonstrated. Investigations with curve flight simulation show a stable performance of the jet engine. Author

N94-34440# Microturbo, Toulouse (France). Chemin du Pont de Rupe.

MICROTURBO'S EXPERIENCE IN THE FIELD OF APU FOR CIVIL AND MILITARY APPLICATIONS AND OUR ROLE IN THE FACE OF THE CHALLENGES OF THE FUTURE [EXPERIENCE DE LA SOCIETE MICROTURBO DANS LE DOMAINE DES GROUPES AUXILIAIRES DE PUISSANCE POUR LES BESOINS MILITAIRES ET CIVILS: NOUVELLES EXIGENCES POUR L'AVENIR]

NORBERT HIRTZ and CHARLES MISCHEL *In* AGARD, Technology Requirements for Small Gas Turbines 14 p (SEE N94-34431 10-07) Mar. 1994 In FRENCH
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

For more than thirty years, Microturbo has designed, developed, and manufactured gas turbines to supply mechanical and pneumatic power for a multitude of applications: airborne and land based; and civil and military. Over the years, continuous technological improvements in engine aerodynamics, thermodynamics, combustion, mechanics, acoustics, and a parallel modernization of fuel management and other engine systems, has enabled Microturbo to develop a range of products which are specifically geared to today's demands and perfectly adapted to those of the future. A summary of the efforts of Microturbo is presented.
Author (revised)

N94-34441# Turbomeca S.A. - Brevets Szydlowski, Bordes (France).

SPECIFICATIONS OF AUXILIARY POWER UNITS FOR CONFORMITY WITH HELICOPTER TURBOSHAFT ENGINES [SPECIFICITE DES GROUPES AUXILIAIRES DE PUISSANCE PAR RAPPORT AUX TURBOMOTEURS D'HELICOPTERE]

JOEL SILET *In* AGARD, Technology Requirements for Small Gas Turbines 14 p (SEE N94-34431 10-07) Mar. 1994 In FRENCH
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

Despite an apparent similarity with helicopter turboshaft engines--in terms of power level, construction, and type of components--Auxiliary Power Units (APU) have special needs that differ from those of helicopter gas turbine engines. The differences can be found in the following areas: integration of aircraft pneumatic and electric systems; combustion chambers; low acoustic levels; low oil consumption; and efficiency requirements.
Author (revised)

N94-34442# Fiat Aviazione S.p.A., Turin (Italy). Direzione Progettazione.

THE DEVELOPMENT OF AN AUXILIARY POWER UNIT FOR A FIGHTER AIRCRAFT

C. VINCI, E. CAMPO, and A. TROVATI *In* AGARD, Technology Requirements for Small Gas Turbines 18 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

The design of an APU is a comprise between several, often conflicting, requirements: installation constraints, performance, duty cycle, weight, reliability, and Life Cycle Cost. This document presents a summary of the significant technology developments that were accomplished on a FiatAvio Auxiliary Power Unit. The APU is a two-spool modular gas turbine that has a pneumatic power rating of 150 HP. A particular effort was dedicated to the development of the full authority digital control system. The APU was certified in 1987, and the first production unit entered service a year and a half later. Author (revised)

N94-34443# Textron Lycoming, Stratford, CT.

ADVANCED CONCEPTS FOR NEXT GENERATION SMALL GAS TURBINE ENGINE COMPRESSORS

ARUN K. SEHRA and HOWARD F. MERRICK *In* AGARD, Technology Requirements for Small Gas Turbines 7 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

The trend in advanced gas turbine engines is towards lightweight, high performance, compact, reliable compression systems. This has created a need for a compression system capable of delivering extremely high stage pressure ratios. Textron Lycoming is currently developing multistage axial compressors with average pressure ratios in excess of 2.5 and single axial stages capable of delivering pressure ratios in excess of 3.5. Major advances in the aerodynamic design techniques and material/structural technologies are necessary to achieve the performance and weight objectives of these compression systems. This paper describes some of the recent advances made in the aero design concepts (swept shock rotors, splittered rotors), computational fluid mechanics, active stabilization system, and material/structural innovations (metal matrix composite titanium aluminide impellers) to meet the challenge of the next generation of gas turbine compression systems. Author (revised)

N94-34444# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).

ADVANCED SMALL HIGH PRESSURE RATIO CENTRIFUGAL COMPRESSOR

M. H. KALOGIANNIS, A. D. LEBLANC, and S. M. PRZYBYTKOWSKI *In* AGARD, Technology Requirements for Small Gas Turbines 6 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

This paper describes the design approach for a high pressure ratio, single-stage, centrifugal compressor that meets current small helicopter engine performance requirements. Test results are provided for a 10:1 pressure ratio single-stage having 80 percent efficiency and 27 percent surge margin. Development of three dimensional computational fluid dynamics has generated the tools to design impellers with improved surge margin while maintaining state of the art efficiency. Further development of Euler and Navier-Stokes codes is required to analytically optimize the impeller-diffuser match and to improve efficiency levels.
Author (revised)

N94-34445# Turbomeca S.A. - Brevets Szydlowski, Bordes (France).

THE CENTRIFUGAL COMPRESSOR, AN ESSENTIAL COMPONENT OF SMALL AND MEDIUM POWER ENGINES [LE COMPRESSEUR CENTRIFUGE, COMPOSANT ESSENTIEL DES TURBOMOTEURS DE PETITE ET MOYENNE PUISSANCE]

P. BELAYGUE and H. VIGNAU *In* AGARD, Technology Requirements for Small Gas Turbines 15 p (SEE N94-34431 10-07) Mar. 1994 In FRENCH Original contains color illustrations
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Originally, the centrifugal compressor formed the basis of the first aeronautical applications of turboshaft engines. Recently, it has been almost exclusively used behind axial compressors as the last compression stage in turbines of small and medium power, with a moderate pressure ratio. As a result of numerous studies which have been carried out during the last two decades, it has been elevated to a key position. Thanks to the progress in the field of analytical tools (concerning aerodynamics, structures, and heat transfer), materials, and processes, its characteristics are such that, besides its traditional use as the last compression stage, it can also perform the following functions: (1) form the only compression stage (up to a compression ratio of 12); and (2) be combined with another centrifugal stage to reach an overall pressure ratio of 20 without using variable geometry. Because of the great simplicity ot the assembly, its intrinsic performance (efficiency, pressure ratio, surge margin, low sensitivity to clearances, and distortions) as well as its ease of integration, it is considered as an essential component to be used in an helicopter engine, the requirements of which can be classified as follows: high specific power, very good reliability, low cost, and performance compromise--cruise specific consumption, emergency power, and response time in transient condition. Its present capacity to run with higher specific flows and the use of variable geometry open new doors to other applications: jet engines and auxiliary power units. Author (revised)

N94-34446*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL AND COMPUTATIONAL RESULTS FROM A LARGE LOW-SPEED CENTRIFUGAL IMPELLER
M. D. HATHAWAY (Army Aviation Research and Development Command, Cleveland, OH.), R. M. CHRISS, J. R. WOOD, and A. J. STRAZISAR *In* AGARD, Technology Requirements for Small Gas Turbines 11 p (SEE N94-34431 10-07) Mar. 1994 See also N94-20136
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

An experimental and computational investigation of the NASA Low-Speed Centrifugal Compressor (LSCC) flow field was conducted using laser anemometry and Dawes' 3D viscous code. The experimental configuration consists of a back-swept impeller followed by a vaneless diffuser. Measurements of the three-dimensional velocity field were acquired at several measurement planes through the compressor. The measurements describe both the throughflow and secondary velocity field along each measurement plane and, in several cases, provide details of the flow within the blade boundary layers. The experimental and computational results provide a clear understanding of the development of the throughflow momentum wake which is characteristic of centrifugal compressors. Author (revised)

N94-34449# Sundstrand Power Systems, San Diego, CA.
COMPACT DIFFUSERS FOR SMALL TRANSONIC COMPRESSORS
COLIN RODGERS *In* AGARD, Technology Requirements for Small Gas Turbines 22 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

Smaller, smarter, airbreathing propelled tactical missiles are being proposed and developed. They will function for various military duties currently performed by larger, limited range missiles or manned surveillance and interdiction aircraft. The extreme compactness of these missiles requires relatively high power density small turbojets. The missile air inlet location and configuration in many of these applications may impose highly distorted compressor inlet flow conditions, with potentially deleterious effects upon compressor performance, both in terms of flow range stability and compression efficiency. Renewed interest has therefore been focused upon alternative compressor design solutions with improved stability, more tolerant to flow distortion effects. In this respect, splitting the compression diffusion process into multirow or tandem cascades has been proposed as a means of attaining increased flow range and efficiency, both in axial and centrifugal compressors. Centrifugal compressors are popular for small, low cost, expendable missiles, especially with compact diffusers permitting reduced frontal area. An experimental study of the effect of a tandem radial cascade diffuser configuration on the performance of a small, high specific speed transonic centrifugal compressor stage is described in this paper. Tests showed the importance of the first tandem row on overall compressor performance and demonstrated higher flow range at the expense of slightly reduced efficiency, as compared to an optimum channel type diffuser. Author

N94-34452*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMBUSTOR TECHNOLOGY FOR FUTURE SMALL GAS TURBINE AIRCRAFT
VALERIE J. LYONS and RICHARD W. NIEDZWIECKI *In* AGARD, Technology Requirements for Small Gas Turbines 17 p (SEE N94-34431 10-07) Mar. 1994 See also N94-13142
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

To enhance fuel efficiency, future advanced small gas turbine engines will utilize engine cycles calling for overall engine pressure ratios, leading to higher combustor inlet pressures and temperatures. Further, the temperature rise through the combustor and the corresponding exit temperature are also expected to increase. This report describes future combustor technology needs for small gas turbine engines. New fuel injectors with large turndown ratios which produce uniform circumferential and radial temperature patterns will be required. Uniform burning will be of greater importance because hot gas temperatures will approach turbine material limits. The higher combustion temperatures and increased radiation at high pressures will put a greater heat load on the combustor liners. At the same time, less cooling air will be available as more of the air will be used for combustion. Thus, improved cooling concepts and/or materials requiring little or no direct cooling will be required. Although presently there are no requirements for emissions levels from small gas turbine engines, regulation is anticipated in the near future. This will require the development of low emission combustors. In particular, nitrogen oxides will increase substantially if new technologies limiting their formation are not evolved and implemented. For example, staged combustion employing lean, premixed/prevaporized, lean direct injection, or rich burn-quick quench-lean burn concepts could replace conventional single stage combustors. Due to combustor size considerations, staged combustion is more easily accommodated in large engines. The inclusion of staged combustion in small engines will pose greater combustor design challenges. Author

N94-34453# General Electric Co., Lynn, MA. Aircraft Engines Div.
COMBUSTOR TECHNOLOGY FOR SMALL AIRCRAFT ENGINES
STEPHEN HOWELL *In* AGARD, Technology Requirements for Small Gas Turbines 9 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

A review of aircraft gas turbine engine performance trends indicates that the smaller the engine the lower are its cycle pressure ratios, which suggests the less the combustor design challenge. This is often reflected in projected development effort. In fact, many aspects of combustor design and performance are adversely affected in smaller engines. Furthermore, when emission reduction requirements are extended to smaller engines, the design comprises needed to meet all performance goals will become particularly acute, and design solutions from large combustors may not be applicable. Author

N94-34454# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).
LOW EMISSION COMBUSTOR TECHNOLOGY FOR SMALL AIRCRAFT GAS TURBINES
H. C. EATOCK and P. SAMPATH *In* AGARD, Technology Requirements for Small Gas Turbines 15 p (SEE N94-34431 10-07) Mar. 1994 Sponsored by Dept. of National Defence and Dept. of Industry, Trade and Commerce Original contains color illustrations
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

This paper addresses small aircraft gas turbine emissions from the viewpoints of environmental impact and control technologies. Improvements achieved in small engine emissions without regulatory control are highlighted, as well as limitations on applicability of 'large-engine' technologies due to scale constraints and the highly cost-sensitive small engine market. Author

N94-34455# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).
REDUCING TEMPERATURE DISTRIBUTION FACTOR (TDF) FOR ADVANCED SMALL GAS TURBINE ENGINES
L. A. PROCIW, T. C. J. HU, and R. R. HASTINGS *In* AGARD, Technology Requirements for Small Gas Turbines 27 p (SEE N94-34431 10-07) Mar. 1994 Original contains color illustrations
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

This paper discusses CFD applications to the analysis and optimization of the temperature distribution factor (TDF) in small, high intensity complex flow field gas turbine combustors. TDF is a term used to describe the nonuniformity of the temperature profile in the combustor exit plane which results from the inability to fully mix out temperature peaks. Hot end durability will be locally affected by temperature peaks whereas total energy exchange is dependent on the gas path bulk average temperature rise. Control of the TDF thus allows increased overall efficiency from both the cycle temperature and cooling load perspective while minimizing hot end distress. Computational fluid dynamic analysis of three dimensional combustor flows and the empirical validation of results are used to demonstrate the effectiveness of CFD as a design tool in this challenging environment. Author

N94-34456# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).
DEVELOPMENT OF A HP-TURBINE FOR A SMALL HELICOPTER ENGINE
H.-J. DIETRICHS, F. MALZACHER, and K. BROICHHAUSEN *In* AGARD, Technology Requirements for Small Gas Turbines 8 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

High specific power and a small SFC are major objectives in the development of advanced turbo shaft engines. The reduced number of turbine stages leads to a considerable increase of their aerodynamic loading. The design and development of a transonic single stage turbine for a pressure ratio Pi equals 3.6 was carried out at MTU in a technology and demonstration program. Results of the extensive annular cascade, cold flow rig, and gas generator engine testing are presented including detailed investigations of transonic vane and blade flow fields, stator/rotor matching effects, and the influence of film cooling flow and tip clearance variations on the turbine performance. Author (revised)

N94-34457# Technische Univ., Dresden (German D.R.). Inst. fuer Energietechnik.
THE INFLUENCE OF THE INLET BOUNDARY LAYERS ON THE SECONDARY LOSSES OF TURBINE STAGES
H. SAUER and H. WOLF *In* AGARD, Technology Requirements for Small Gas Turbines 6 p (SEE N94-34431 10-07) Mar. 1994 Sponsored by Ministry of Science and Technology
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

The efficiency level of turbine stages with small blade height is mainly determined by the endwall losses because they are significantly higher than the profile losses. In spite of extensive research work in this field, there are still some unsatisfactorily solved problems. The paper deals with two problems: the increase of the endwall losses downstream the cascade and the influence of the cascade inlet boundary layer thickness on the endwall losses. Because the inlet boundary layer is twisted mainly by the tip clearance vortex of the cascade upstream, the effect of a skewed inlet boundary layer is shown as well. Finally, measurement results of a turbine stage with blade height L equals 30 mm (D(sub m)/L equals 13) are shown for the cases with and without shroud. Author (revised)

N94-34458# National Research Council of Canada, Ottawa (Ontario). Turbomachinery Aerodynamics Group.
EFFECT OF TIP CLEARANCE ON THE PERFORMANCE OF A HIGHLY LOADED TURBINE STAGE
U. W. SCHAUB, E. VLASIC, and S. H. MOUSTAPHA *In* AGARD, Technology Requirements for Small Gas Turbines 11 p (SEE N94-34431 10-07) Mar. 1994 Prepared in cooperation with Pratt and Whitney Aircraft of Canada Ltd., Longueuil, Quebec
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

This paper describes the performance of a highly loaded turbine stage with a pressure ratio of 3.75 and a stage loading of 2.47. Tests were carried out with two rotor blade counts at design and 70 percent speeds for a range of tip clearances from 1.1 to 2.1 percent of blade span. The results are presented in the form of radial distribution of stage exit swirl and efficiency and are compared with the prediction of a 3-D Euler flow solver. The measured efficiency drop for a 1 percent change in tip clearance is 2.6 and 1.1 percentage points at 100 and 70 percent speed, respectively. The efficiency drop reduced from 2.6 to 1.7 percentage points with a 33 percent reduction in blade count. The effect of clearance variation on stage exit conditions was seen to extend over most of the blade span. Author

N94-34459*# Allied-Signal Aerospace Co., Phoenix, AZ. Turbine Aerodynamics.
DESIGN AND AERODYNAMIC PERFORMANCE EVALUATION OF A HIGH-WORK MIXED FLOW TURBINE STAGE
REMO N. NERI, THOMAS J. ELLIOTT, DAVID N. MARSH, and KESTUTIS C. CIVINSKAS *In* AGARD, Technology Requirements for Small Gas Turbines 16 p (SEE N94-34431 10-07) Mar. 1994 Sponsored by NASA. Lewis Research Center and Army Research Lab.
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

As axial and radial turbine designs have been pushed to their aerothermodynamic and mechanical limits, the mixed-flow turbine (MFT) concept has been projected to offer performance and durability improvements, especially when ceramic materials are considered. The objective of this NASA/U.S. Army sponsored mixed-flow turbine (AMFT) program was to determine the level of performance attainable with MFT technology within the mechanical constraints of 1997 projected ceramic material properties. The MFT geometry is similar to a radial turbine, exhibiting a large radius change from inlet to exit, but differing in that the inlet flowpath is not purely radial, nor axial, but mixed; it is the inlet geometry that gives rise to the name 'mixed-flow'. The 'mixed' orientation of the turbine inlet offers several advantages over radial designs by allowing a nonzero inlet blade angle yet maintaining radial-element blades. The oblique inlet not only improves the particle-impact survivability of the design, but improves the aerodynamic performance by reducing the incidence at the blade inlet. The difficulty, however, of using mixed-flow geometry lies in the scarcity of detailed data and documented design experience. This paper reports the design of a MFT stage designed with the intent to maximize aerodynamic performance by optimizing design parameters such as stage reaction, rotor incidence, flowpath shape, blade shape, vane geometry, and airfoil counts using 2-D, 3-D inviscid, and 3-D viscous computational fluid dynamics code. The aerodynamic optimization was accomplished while maintaining mechanical integrity with respect to vibration and stress levels in the rotor. A full-scale cold-flow rig test was performed with metallic hardware fabricated to the specifications of the hot ceramic geometry to evaluate the stage performance. Author

N94-34460# Cranfield Inst. of Tech., Bedford (England). Dept. of Turbomachinery and Engineering Mechanics.
NOZZLE GUIDE VANE FLOW IN RADIAL INFLOW TURBINES
SOHAIL H. ZAIDI and ROBIN L. ELDER *In* AGARD, Technology Requirements for Small Gas Turbines 13 p (SEE N94-34431 10-07) Mar. 1994 Sponsored by European Research Office
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

Radial inflow turbines have various applications in industry and are being used as major components of gas turbines and turbochargers. The details of the flow phenomena within these machines are ill-define especially in small high speed units where small passages and high velocities are involved. To gain a better understanding of these flow processes, a small radial inflow turbine has been studied using laser anemometry. The main area of interest has been the region between the nozzle guide vanes and the turbine rotor. The flow in this region has been investigated at several positions across the nozzle guide vane pitch and span. The influence of the passing blades on the guide vane flow has also been studied. The results obtained have been compared with those from a previously studied (comparative) unit. The flow phenomena from the two machines differ quite markedly in the extent of the distortion observed at the nozzle guide vane and rotor interface. Author

N94-34461# Ulstein Turbine A/S, Kongsberg (Norway).
TURBINE BLADE DYNAMICS AND BLADE-VANE INTERACTION IN A RADIAL INFLOW TURBINE
A. WILSON and T. UTENGEN *In* AGARD, Technology Requirements for Small Gas Turbines 11 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

This paper is divided into two parts. In the first part it describes the aerodynamic design of radial flow nozzle guide vanes (NGV's) and the excitation forces from the NGV flow on the rotor. The second part, which is the section on structural analysis, describes the design efforts made for avoiding serious vibration problems in a radial inflow turbine. Author

N94-34465# National Research Council of Canada, Ottawa (Ontario). Structures and Materials Lab.
HOT SECTION MATERIALS FOR SMALL TURBINES
A. K. KOUL *In* AGARD, Technology Requirements for Small Gas Turbines 10 p (SEE N94-34431 10-07) Mar. 1994
(Contract(s)/Grant(s): IAR PROJ. CJ501)
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

This paper reviews unique requirements for hot section materials for small (less than 5000 lb. St.) axial flow turbines. Recent developments in integrally cast wheels, conventionally cast blades and vanes, directionally solidified and single crystal blades, conventionally forged and gatorized discs, and coatings technologies are summarized. Hot section materials trends for

future engine designs, particularly in light of USAF MIL-STD-1783 requirements, are also discussed. Author

N94-34607# Wright Lab., Wright-Patterson AFB, OH. Turbine Engine Div.
PROGRESS AND PURPOSE OF IHPTET PROGRAM
RICHARD J. HILL *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 8 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03

IHPTET is the Integrated High Performance Turbine Engine Technology initiative. This paper discusses the purpose (background goals and applications) and the progress of IHPTET. IHPTET is 30 percent complete and achieving significant success in advancing turbine engine technology levels. The future of IHPTET is bright. IHPTET developed technologies are being applied to both military and commercial turbine engines -- both new engines and fleet modernization's. IHPTET is the technology base for all future military systems and the springboard for many new commercial engines. Author

N94-34608# Rolls-Royce Ltd., Bristol (England).
ENGINE CHARACTERISTICS FOR AGILE AIRCRAFT
K. R. GARWOOD, G. S. HODGES, and H. E. ROGERS *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 8 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03

A number of different factors drive and constrain the development of future technology. This paper looks at the current perspective on the development of agile aircraft systems and more specifically, the engine characteristics these demand. Having identified the desirable engine characteristics, the key technologies required to enable them are discussed. It is proposed that the optimum agile aircraft system will be achieved given these technologies by considering the best way in which the engine should be 'rated' to fulfill the operational requirements envisaged. Author

N94-36333# Naval Air Warfare Center, Warminster, PA. Aircraft Div.
PROPULSION SYSTEM SELECTION FOR A HIGH ALTITUDE LONG ENDURANCE AIRCRAFT
JOHN D. CYRUS and JOSEPH FRANZ *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A02/MF A03

This paper addresses the major propulsion system options for High Altitude Long Endurance aircraft internal combustion engines, turbine engines and fuel cells. The paper identifies the technology drivers for the vehicle and assesses the secondary equipment requirements for the various system options. Critical technologies and development requirements are addressed in terms of mission capability for both near-term and advanced systems. This AGARDograph was sponsored by the Flight Mechanics Panel. Author

N94-36334# Rolls-Royce Ltd., Bristol (England).
PROPULSION SYSTEM TECHNOLOGIES FOR LONG RANGE AND LONG ENDURANCE AIRCRAFT
K. R. GARWOOD *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A02/MF A03

The NATO requirement for increased range and endurance of aircraft is also associated with the necessity to reduce the initial and life cycle costs of these aircraft. Consideration of these conflicting requirements leads to the prioritization of engine technologies for different vehicle types and presented here are views of engine manufacturers addressing these challenges over the range of aircraft. This paper will discuss the prioritization of technologies required for the range of air vehicles and examine how increases in endurance and range affect the balance of technology within each propulsion unit type. It is convenient to group the vehicles in the following way: transport, tanker, AWACS; maritime patrol; combat; and special purpose. Each grouping has the challenges of range or duration subject to its class, although clearly in absolute terms the range of transport vehicles is significantly different from that of a combat aircraft. It is primarily these differences in the groupings that give rise to the differences in technology prioritization. Derived from text

N94-36335# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany).
THE STRATO 2C PROPULSION SYSTEM: A LOW COST APPROACH FOR A HIGH ALTITUDE LONG ENDURANCE AIRCRAFT
H. TOENSKOETTER *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 6 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A02/MF A03

For the STRATO 2C - a High Altitude Long Endurance Research Aircraft - a low cost propulsion system was designed and is now under development. The approach to achieve the aim of low development procurement and in-service costs is a compound propulsion system based on a highly supercharged liquid cooled piston engine with charge air inter-cooling and the extensive usage of available components. The concept of the propulsion system and the main components are described. Aspects of controlling the three-stage turbocharger system are discussed. The way to realize the power plant in three years is presented and the test program is addressed. Author

N95-19017# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
MATHEMATICAL MODELS OF GAS TURBINE ENGINES AND THEIR COMPONENTS [LES MODELES MATHEMATIQUES DES TURBOMOTEURS ET DE LEURS ORGANES]
Dec. 1994 183 p Lecture series held in Cleveland, OH, 7-8 Dec. 1994, in Wessling, Germany, 12-13 Dec. 1994 and in Paris, France, 15-16 Dec. 1994
(AGARD-LS-198; ISBN-92-836-1008-3) Copyright Avail: CASI HC A09/MF A02

This Lecture Series will present and discuss the scientific problems of modern mathematical simulation of gas turbine engines and their components. Some peculiarities of complex multicomponent and multidisciplinary models for whole flow passage of bypass gas turbine engine, core, multistage compressors and turbines, and other engine components will be studied. Solutions of steady and unsteady problems are given using high efficiency monotone numerical methods and the theoretical bases of these methods are presented. Many practical results of aerodynamic and thermostress simulations for engine components are shown. These results are compared widely with experimental data for accurate verification of developing computational codes. This Lecture Series, endorsed by the Propulsion and Energetics Panel of AGARD, has been implemented by the Technology Cooperation Program. For individual titles, see N95-19018 through N95-19026.

N95-19020# Central Inst. of Aviation Motors, Moscow (Russia).
THE MATHEMATICAL MODELS OF FLOW PASSAGE FOR GAS TURBINE ENGINES AND THEIR COMPONENTS
RAVIL Z. NIGMATULLIN and MIKHAIL J. IVANOV *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 28 p (SEE N95-19017 05-07) Dec. 1994
(AGARD-LS-198) Copyright Avail: CASI HC A03/MF A02

Mathematical models for gas turbine engines and installation component flow passages based on real 3D geometry of flow passages, in particular spatial shape of blades, are considered. The models are based on numerical solving of unsteady Euler equations and so it allows simulation of some unsteady transitional functioning regimes of engines and installations together with steady ones. The models take into consideration the viscous losses, leakage in axial gaps and tip clearances, cooling air injection and selection. The first level mathematical models are based on 2D steady and unsteady methods on S(sub 1) and S(sub 2) surfaces. Some features of numerical algorithms based on these methods are considered. The second level models are based on 3D approaches anywhere in computational domains excluding the middles of axial gaps between neighboring blade rows where for the simplification of the problem the averaging in angular direction is fulfilled. Author (revised)

N95-19021# Central Inst. of Aviation Motors, Moscow (Russia).
SIMULATION OF MULTIDISCIPLINARY PROBLEMS FOR THE THERMOSTRESS STATE OF COOLED HIGH TEMPERATURE TURBINES
VALEREY K. KOSTEGE, V. A. HALTURIN, and V. G. SUNDURIN *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 15 p (SEE N95-19017 05-07) Dec. 1994
(AGARD-LS-198) Copyright Avail: CASI HC A03/MF A02

Numerical models for the thermostress state analysis of turbine rotor elements are discussed. Steady and unsteady temperature fields are calculated and result in solution of conjugate heat and hydraulic problems for blades (quasi three-dimensional model) for disk (two-dimensional model) and for the whole cooled rotor (three-dimensional model). A lot of attention is given to mass flow calculation in blade passages and turbine circumferential disk cavities. They are determined by using experimental data for pressure loss and generalized dependencies for friction and heat transfer coefficients on stators and rotors surfaces. On external blade surfaces the ,boundary conditions are defined from the solution of two-dimensional and three-dimensional gas dynamics problems and corrected from experimental data base for film cooling. The thermostress state is calculated by a finite element method for realistic geometry using common equations of elasticity theory. Author

N95-19022# Central Inst. of Aviation Motors, Moscow (Russia).
APPLICATION OF MULTICOMPONENT MODELS TO FLOW PASSAGE SIMULATION IN MULTISTAGE TURBOMACHINES AND WHOLE GAS TURBINE ENGINES
RAVIL Z. NIGMATULLIN *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 17 p (SEE N95-19017 05-07) Dec. 1994
(AGARD-LS-198) Copyright Avail: CASI HC A03/MF A02

Some features of used numerical algorithms for gas turbine engines components flow simulation are considered. Among them are topology of computational grids in 2D and 3D cases for flow passages of complex geometry, details of realization of conservative scheme at joints of different grids. In S(sub 2)-calculations it is necessary to consider the problem of inlet and outlet angles; in Euler calculation the ways of accounting for viscous loss effects are briefly described. Examples of calculations of flow through by-pass engine components are presented. Author

N95-19023# Central Inst. of Aviation Motors, Moscow (Russia).
SIMULATION OF STEADY AND UNSTEADY VISCOUS FLOWS IN TURBOMACHINERY
VLADISLAV G. KRUPA *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 39 p (SEE N95-19017 05-07) Dec. 1994
(AGARD-LS-198) Copyright Avail: CASI HC A03/MF A02

A Navier-Stokes code has been used to compute the viscous turbulent cascade flows. The numerical method employs implicit high-order accurate Godunov scheme and a two equation (q - omega) turbulence model based on the integration to the wall. The generation of the O-H grid system for viscous cascade flow simulations is discussed. Numerical solutions were obtained for 2D and 3D turbine cascade flows and 2D unsteady rotor-stator interactions. Available experimental data are used for verification of the computed results. Author

N95-19024# Central Inst. of Aviation Motors, Moscow (Russia).
APPLICATION OF MULTIDISCIPLINARY MODELS TO THE COOLED TURBINE ROTOR DESIGN
VALERY K. KOSTEGE, V. D. VENEDIKTOV, and A. V. GRANOVSKII *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 10 p (SEE N95-19017 05-07) Dec. 1994
(AGARD-LS-198) Copyright Avail: CASI HC A02/MF A02

A computer program for designing turbine vane and blade cooling systems is discussed. This program is based on the complex use of 2D and 3D gas dynamic, heat-transfer and thermostress models. FEM Thermostress models are formatted based on geometry data from the computer design system. One-dimensional mass flow and conjugate thermal models are quickly created by using graphic dialogue regimes for different cooling systems. Quasi-3D and 3D thermostress models are used to carry out cooling system optimization or comparison of alternative cooling systems. Author

N95-19025# Central Inst. of Aviation Motors, Moscow (Russia).
VERIFICATION OF MULTIDISCIPLINARY MODELS FOR TURBOMACHINES
VALEREY K. KOSTEGE *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 7 p (SEE N95-19017 05-07) Dec. 1994
(AGARD-LS-198) Copyright Avail: CASI HC A02/MF A02

Accurate prediction of the temperature distribution in rotating blades is an important and difficult task. An approach for the verification of hydraulic and thermal models in real blades is discussed in the lecture. For static conditions, predicted local internal convective heat transfer coefficients on blades are corrected using a quasi-3D thermal-hydraulic model with the blade unsteady surface temperatures measured by the Thermovision system. External boundary conditions are corrected using the blade base surface temperatures measured by thermocouples on a hot static rig. The final identification of the models is carried out using measurements of the gas temperature distribution within the rotating blade passage, and the measured blade external surface temperature in the engine. Author

N95-19026# Central Inst. of Aviation Motors, Moscow (Russia).
PERSPECTIVE PROBLEMS OF GAS TURBINE ENGINES SIMULATION
MIKHAIL J. IVANOV *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 19 p (SEE N95-19017 05-07) Dec. 1994
(AGARD-LS-198) Copyright Avail: CASI HC A03/MF A02

The purpose of the last lecture is to present the activity of CIAM in the field of the development of Computer Turbojet Test Technology based on aero-engine models of high 3D level. Using this technology the aero-engine design may be transformed into new quality. It's the predictions of steady and transient working processes, performance and efficiency on the first stage of engine design (without the real metal engine testing). These aero-engine models must accompany the whole engine life - from design to production and use on aircraft. Author

N95-19653# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
EROSION, CORROSION AND FOREIGN OBJECT DAMAGE EFFECTS IN GAS TURBINES [LES CONSEQUENCES DE L'ENDOMMAGEMENT DES TURBINES A GAZ PAR EROSION, CORROSION ET OBJETS ETRANGERS]
Nov. 1994 338 p In ENGLISH and FRENCH Symposium held in Rotterdam, Netherlands, 25-28 Apr. 1994 Original contains color illustrations
(AGARD-CP-558; ISBN-92-836-0005-3) Copyright Avail: CASI HC A15/MF A03

The Conference Proceedings contains 31 papers presented at the Propulsion and Energetics Panel Symposium on Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines which was held from 25-28th April 1994, in Rotterdam, The Netherlands. The Technical Evaluation Report and the Keynote Address are included at the beginning and discussions follow most papers. The Symposium was arranged in the following Sessions: Operational Experience and Requirements (7); Deposition and Erosion (7); Foreign Object Damage (5); Coatings, Repairs and Materials Aspects - 1 (4); Coatings, Repairs and Materials Aspects - 2 (7); and Testing and Certification Procedures (1). For individual titles, see N95-19654 through N95-19684.

N95-19654# Rolls-Royce Ltd., Bristol (England).
OUT OF AREA EXPERIENCES WITH THE RB199 IN TORONTO
M. G. DOWN and M. J. WILLIAMS *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 7 p (SEE N95-19653 05-07) Nov. 1994
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The Turbo Union RB 199 engine was developed during the late 1960's / early 1970's to meet a specification requirement aimed at defense of the Western European NATO alliance countries against the (then) perceived threat. During the latter part of the 1980's Tornado aircraft were delivered to the Royal Saudi Air Force and, supplemented by deployed units from the Royal Air

Force, were engaged in an operational role during 1990 / 1991. Aircraft operations in the Saudi Arabia climates and natural environment created problems with engine life, hitherto not encountered in the European area of operation, nor during many RAF overseas deployments, including North America. These problems, mainly concerned with turbine blade contamination from airborne sand, were alleviated by the introduction of unique engine maintenance management techniques and eliminated by design changes. Author

N95-19655# Defence Research Agency, Farnborough, Hampshire (England). Air Vehicle Performance Dept.

THE OPERATION OF GAS TURBINE ENGINES IN HOT AND SANDY CONDITIONS: ROYAL AIR FORCE EXPERIENCES IN THE GULF CONFLICT

R. C. SIRS *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 8 p (SEE N95-19653 05-07) Nov. 1994

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During the initial phase of the Gulf Crisis, the principal instrument at the disposal of the British Government which could respond in time was air power. This situation continued, and throughout the period of military build up and subsequent conflict air power remained a dominant factor. During the period, many equipment modifications were incorporated to increase both performance and reliability, and the gas turbine engines which powered the RAF's aircraft were no exception. However in some cases, engines were operated at a much increased flying rate in harsh operating conditions in standard configuration. This paper reviews the operating experiences and some of the modifications incorporated, including the subsequent effect on aero-engine reliability trends. Author

N95-19656# Army Aviation Systems Command, Saint Louis, MO. Directorate for Engineering.

US ARMY ROTORCRAFT TURBOSHAFT ENGINES SAND AND DUST EROSION CONSIDERATIONS

VERNON R. EDWARDS and PETER L. ROUSE *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 10 p (SEE N95-19653 05-07) Nov. 1994

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The impact of operating in a sand and dust environment on U.S. Army rotorcraft turbine engines has been a major concern since the first turbine powered UH-1 Iroquois (Huey) helicopter was fielded in the early 1960s. The implication on turbine engine performance and durability had not sufficiently been recognized, or addressed, in early engine designs. Early engine military specifications had been primarily concerned with U.S. Air Force 'jet' engines for fixed wing aircraft. Although these early specifications included sand and dust requirements relative to ingestion capability and test substantiation, actual rotorcraft field experience was not considered, nor, in fact, was actual data available. This paper provides a brief history of the impact of operation in sand and dust and operational considerations on U.S. Army rotorcraft turbine engines. The general effects of sand and dust erosion, compaction, deformation, glassing, etc., on engine turbomachinery will be discussed. Finally, the results of operation in Southeast Asia, and during Desert Shield/Desert Storm, possibly the worse case operational environment encountered to date, will be presented. Author

N95-19657# Rolls-Royce Ltd., Bristol (England).

FUTURE DIRECTIONS IN HELICOPTER PROTECTION SYSTEM CONFIGURATION

DARRELL L. MANN and GORDON D. WARNES *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 12 p (SEE N95-19653 05-07) Nov. 1994

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Recent events have highlighted the fact that none of the currently available turboshaft intake protection systems, whether they be the permanent fit IPS or mission specific vortex pack types, have an adequate sand/dust separation capability. Evidence has been amply provided by low engine life, consequent support logistics problems and the necessity for development of short term emergency measures. The paper seeks to quantify the extent of the problem and define the solutions which will be required if a repeat of past experiences is to be avoided. The paper describes the directions which particles separator technology must take in order to meet future requirements. A further important aspect of future directions is the drive for an increase in an engine's ability to resist damage; the paper identifies those areas of the engine which are most prone to damage, comments on the need to strike the right balance between resistance and removal, and discusses the increasing value of sophisticated computer based design methodologies. Author

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NAVY FOREIGN OBJECT DAMAGE AND ITS IMPACT ON FUTURE GAS TURBINE ENGINE LOW PRESSURE COMPRESSION SYSTEMS

PETER CHARLES DIMARCO *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 9 p (SEE N95-19653 05-07) Nov. 1994

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Foreign Object Damage (FOD), Domestic Object Damage (DOD), bird ingestion, and ice ingestion are all necessary factors to be considered in the design of reliable and maintainable fan systems for future U.S. Navy aircraft applications. The high rate of fan damage reported in U.S. Navy engines and its impact on repair and maintenance requirements such as engine down time, level of repair, and number of spares have caused the Navy in recent years to scrutinize the requirements which must be met in order to design a more reliable and rugged yet highly maintainable fan system for future aircraft. This paper reports the results of an investigation into the occurrences of Foreign Object Damage in several U.S. Navy aircraft, the repair approaches presently used by the U.S. Navy, and investigates the implications which these considerations present to the design of more damage tolerant fan systems. It further investigates the trade-offs in future turbomachinery design which balance gas turbine engine performance payoff against supportability and maintainability onboard ship. Author

N95-19659# Scandinavian Airlines System, Oslo (Norway).

SCANDINAVIAN AIRLINES SYSTEMS EXPERIENCE ON EROSION, CORROSION AND FOREIGN OBJECT DAMAGE EFFECTS ON GAS TURBINES

P. STOKKE *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 10 p (SEE N95-19653 05-07) Nov. 1994

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This article summarizes SAS' experience on engine FOD and compressor erosion. It will mainly focus on type of damages, debris sources, modifications developed, development of maintenance and inspection method to cope with the problem, revision of operational procedures etc. In addition the added maintenance costs implied by FOD and erosion will be discussed, as also will be the special considerations to be used for cold winter operations. Author

N95-19660# General Electric Co., Cincinnati, OH. Aircraft Engines Div.

MODERN TRANSPORT ENGINE EXPERIENCE WITH ENVIRONMENTAL INGESTION EFFECTS

T. L. ALGE and J. T. MOEHRING *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines (SEE N95-19653 05-07) Nov. 1994

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Modern propulsion engines have achieved a high level of reliability while manufacturers and users are always striving to further improve the safety record. The drive for safety in single-engine aircraft has resulted in safer multiple-engine applications. In modern turbofan-powered transports it is extremely unlikely that a failure intrinsic to an engine would initiate a sequence of events which could result in loss of capability for continued safe flight and landing. These rare events are limited to uncontained rotor disk fracture or uncontrolled fire. Of greater concern today are the non-intrinsic, common-cause events which involve power loss of more than one engine. These are externally-inflicted occurrences such as ingestion events or common-cause maintenance events resulting in simultaneous loss of power on more than one engine. The most frequent are those ingestion events involving products of the flying environment - flocking birds, ice, volcanic ash and extreme inclement weather. This environmental ingestion hazard viewed in overview is the primary

subject of this paper. There is a body of knowledge on each of these subjects. Data from field operations and engine experience have provided guidelines for recognition of an occurrence and the proper action response. The primary precaution however remains - be aware, prevent, communicate and avoid. Author

N95-19661# Oxford Univ., Oxford (England). Dept. of Engineering Science.

PARTICLE DEPOSITION IN GAS TURBINE BLADE FILM COOLING HOLES

V. H. M. KUK, P. T. IRELAND, T. V. JONES, and M. G. ROSE (Rolls-Royce Ltd., Derby, England.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 18 p (SEE N95-19653 05-07) Nov. 1994 Original contains color illustrations

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The aerodynamic processes leading to film cooling hole blockage have been investigated experimentally in large scale models of idealized internal cooling passages. The experimental scaling included reproducing engine cooling passage and hole Reynolds numbers together with a new dimensionless group which was matched experimentally to ensure that the measured particle trajectories were engine representative. It has been possible to achieve correct dimensional scaling with particles one thousand times larger than engine size. Simple visualization of the particle trajectories showed concentrations of impact locations inside holes normal to and inclined to the cooling passage surface. No attempt was made to model interaction between the particles and the passage walls. A new instrument has been developed to measure the concentration of particle impacts. Use of the device provides a fast and convenient way of measuring particle impact distributions. The regions of high impact concentration are consistent with blockage structures found in engines after service. The process of internal blockage of film cooling holes has been shown to be due to inertia driven particles of the order of 1 micron in diameter. Flow conditions immune from impact concentration and hence the blockage process have been identified for the inclined film cooling hole. Author

N95-19662# Cincinnati Univ., OH. Dept. of Aerospace Engineering and Engineering Mechanics.

EXPERIMENTAL AND NUMERICAL SIMULATIONS OF THE EFFECTS OF INGESTED PARTICLES IN GAS TURBINE ENGINES

A. HAMED and W. TABAKOFF *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 13 p (SEE N95-19653 05-07) Nov. 1994

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Particles ingested in gas turbine engines follow trajectories that generally deviate from the flow streamlines and impact the component surfaces causing erosion damage. This paper deals with the experimental and numerical simulations of particle dynamics including surface interactions and the associated blade erosion in gas turbine engines. The experimental studies of particle surface impacts include the nonintrusive measurements of particle bounce conditions and the erosion testing of blade materials and blade coatings. Data obtained in the University of Cincinnati's high temperature erosion test facility at temperatures up to 1500 F for different alloys and coatings are presented. The numerical studies to simulate the particle dynamics in the turbomachines are described. Results of combined experimental and computational modeling are presented for the particle dynamics, the associated turbomachinery blade erosion, and performance loss. The probabilistic modeling of the experimentally measured variance in the particle bounce conditions and the loss of performance associated with particle ingestion are discussed. Author

N95-19663# Cranfield Univ., Bedford (England). School of Mechanical Engineering.

PARTICLE TRAJECTORIES IN GAS TURBINE ENGINES

S. C. TAN, R. L. ELDER, and P. K. HARRIS *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 13 p (SEE N95-19653 05-07) Nov. 1994

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This paper describes the technique of particle trajectory modeling in gas turbine engines with applications in helicopter inertial particle separator, axial ad centrifugal compressor. The model can be used with most CFD codes which utilize the finite volume (or element) techniques. Some qualitative validations were carried out using a laser transit anemometer in a particle separator and results show good comparison with predictions. The anemometer was also used to obtain restitution data for several target materials using quartz particle of different sizes at a range of impact velocities and angles. Author

N95-19664# Defence Research Agency, Farnborough, Hampshire (England).

THE CALCULATION OF EROSION IN A GAS TURBINE COMPRESSOR ROTOR

G. C. HORTON, H. VIGNAU (Turbomeca S.A. - Brevets Szydlowski, Bordes, France.), and G. LEROY (Turbomeca S.A. - Brevets Szydlowski, Bordes, France.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 14 p (SEE N95-19653 05-07) Nov. 1994

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Erosion of the turbomachinery and other components in helicopter gas turbines operating in a sandy environment is a significant problem. In order to better understand the mechanics of such erosion, and to enable the design of components better able to withstand it, a means of modelling erosion is needed. Such a method has been developed at Turbomeca. It consists of a method of predicting the trajectories of the particles within the component, on the basis of a prescribed aerodynamic field and taking into account rebounds from the walls, together with correlations for the erosion caused by impacts of the particles with the walls. The various aspects of the method have been validated by comparison with available experimental data and these comparisons are presented. Predictions of particle trajectories in two types of particle separator and in two gas turbine compressors (axial and centrifugal) are also presented, together with some comparisons with experiment. Author

N95-19665# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).

PERFORMANCE DETERIORATION OF AXIAL COMPRESSORS DUE TO BLADE DEFECTS

J. SCHMUECKER and A. SCHAEFFLER *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 6 p (SEE N95-19653 05-07) Nov. 1994

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During flight operation the engine swallows sand or other hard particles usually from the runway. Passing through the compressors they will damage the blades, erode the coating and deteriorate seals. The submitted paper presents some measurements, which show the effect on compressor performance due to the most important and frequent defects. The investigation - conducted at high pressure compressors - includes tests with reworked blades at leading and trailing edges, rounded rotor tips and increased tip clearances. The results are summarized in easy to handle correlations, which enables the user to estimate the deterioration and to fix repair rules within the allowed performance loss range. Author

N95-19666# National Research Council of Canada, Ottawa (Ontario). Inst. for Aerospace Research.

EROSION OF T56 5TH STAGE ROTOR BLADES DUE TO BLEED HOLE OVERTIP FLOW

B. C. BARRY and T. C. CURRIE *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 10 p (SEE N95-19653 05-07) Nov. 1994

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Severe trailing edge erosion of ALLISON T56 gas turbine 5th and 10th stage compressor blades has been observed in Field Service Evaluations and sand ingestion tests. The erosion typically occurs within 3 mm of the blade tip and has been attributed to overtip flow produced by the bleed holes present over the 5th and 10th stage rotors. The overtip flow through the 5th stage bleed holes of an operating T56 has been surveyed with a laser two-focus (L2F) velocimeter in order to identify the features of the flow field responsible for the tip erosion. Two-dimensional measurements were made at 4 spanwise locations in the outer 25 percent of the span. Three-dimensional measurements were made at three spanwise stations within 7 mm of the blade tip (15 percent of span). The flow was found to be unaffected by the bleed holes beyond 3-4 mm from the blade tip. This result is consistent with erosion patterns observed on service-exposed

blades and blades subjected to accelerated erosion in sand ingestion tests. Author

N95-19668# Palermo Univ. (Italy). Dipt. di Meccanica e Aeronautica.

AN AIRBORNE MONITORING SYSTEM FOR FOD AND EROSION FAULTS

GIUSEPPE LOMBARDO and GIOVANNI TORELLA (Italian Air Force Academy, Naples, Italy.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 12 p (SEE N95-19653 05-07) Nov. 1994

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FOD and erosion are the events causing the most part of accidental damages in gas turbine engines. When FOD is not destroying or when erosion is in progress the performance level decreases and the necessity of unscheduled maintenance actions becomes quite real. Moreover when there is a light FOD, or the erosion process is constant in time, it may be difficult to detect the exact cause of performance decrease and to plan the most effective maintenance action. This paper deals with the results of a study carried out for developing an Engine Condition Monitoring system particularly suitable for detecting the MicroFOD and erosion effects in gas turbines. The developed numerical code has been applied to a single spool turboshaft engine with free power turbine. The obtained results are presented and discussed. Author

N95-19669# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).

DESIGN OF FAN BLADES SUBJECTED TO BIRD IMPACT [CONCEPTION DES AUBES FAN SOUMISES A L'IMPACT D'OISEAUX]

P. VIGNOLLES, P. X. BUSSONNET, and J. TALBOTEC *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 11 p (SEE N95-19653 05-07) Nov. 1994 In FRENCH Original contains color illustrations

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The quality of fan blades in terms of behavior is one of the major parameters affecting the safety of modern aircraft driven by engines with strong by-pass ratio. The reinforcements defined as necessary in certain areas of the profiles of the fan blades must be a compromise between the objectives of mechanical resistance and aerodynamic performance. SNECMA developed a methodology to forecast the impact behavior of the fan blades based on a mathematical model. In parallel, the progress made in aerodynamics made it possible to predict the consequences of these stresses related to ingestion on aerodynamic performance and still maintain high levels of performance. Author

N95-19670# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).

IMPACT LOADING OF COMPRESSOR STATOR VANES BY HAILSTONE INGESTION

J. FRISCHBIER *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 12 p (SEE N95-19653 05-07) Nov. 1994

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Impacts of 1 inch diameter ice bullets onto stator vanes of the first stage of an axial compressor were investigated at an impact velocity of $v = 257$ m/s. The analytical and experimental simulations of typical hailstone ingestions were performed with special emphasis on damage effects of the thin leading edges of the hidden titanium vanes. The paper includes a comprehensive overview of the ice properties used in the analytical model regarding elastic constants, strain rate dependent strength and crack propagation under compression. The influence of different impact positions and ice properties was investigated in the analytical simulations. In all cases the highest stresses occur at the leading edge of the hidden vane. When the center of impact is placed on the leading edge plastic deformations are expected and localized microcracks cannot be excluded. When the target point is positioned on the suction side of the vane (air foil flank) the energy transfer and the loading is high, but the deformations remain elastic. For verification shooting tests of ice bullets on a complete stator were performed. The ice balls were made by freezing water in liquid nitrogen and the impacts were recorded with a high speed camera. The observed leading edge deflections are in good agreement with the calculated values, but in no case plastic deformations or cracks were detected. Author

N95-19671# Oxford Univ., Oxford (England). Dept.of Engineering Science.

SOFT BODY IMPACT ON TITANIUM FAN BLADES

D. A. HUGHES, I. MARTINDALE (Rolls-Royce Ltd., Derby, England.), and C. RUIZ *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 5 p (SEE N95-19653 05-07) Nov. 1994

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The strength of titanium fan blades under soft body impact has been studied by means of panel tests. The panels, representing blades with various leading edge profiles, were exposed to oblique impact in a gas gun facility by launching a block of gelatine at speeds of up to 600 m/s. High speed photography, at 100,000 f.p.s. and strain gauges provide a record of the deformation. Failure occurred either as a result of the deformation or localized tearing. Tearing was taken as determining the limiting strength of the blade, which was found to be strongly dependent on the leading edge profile. Author

N95-19672*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

ICE-IMPACT ANALYSIS OF BLADES

C. C. CHAMIS, P. L. N. MURTHY, S. N. SINGHAL (NYMA, Inc., Brook Park, OH.), and E. S. REDDY (NYMA, Inc., Brook Park, OH.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 12 p (SEE N95-19653 05-07) Nov. 1994

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A computational capability is described for evaluating the ice-impact on engine blades made from composites. The ice block is modeled as an equivalent spherical object and has the velocity opposite to that of the aircraft with direction parallel to the engine axis. A finer finite element mesh is used for a portion of the blade near the impact region compared to the course mesh for the rest of the blade. The effects of ice size and velocity on the average leading edge strain are evaluated for a simulated unswept composite propfan blade. Parametric studies are performed to assess the blade structural responses due to the ice-impact at various locations along the span. It is found that: (1) for a given engine speed, a critical ice speed exists that corresponds to the maximum strain; and (2) the tip bending type frequencies increase after impact while the torsion frequencies decrease. Author

N95-19673# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).

DAMAGE OF HIGH TEMPERATURE COMPONENTS BY DUST-LADEN AIR

P. KOENIG, T. MILLER, and A. ROSSMANN *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 12 p (SEE N95-19653 05-07) Nov. 1994 Original contains color illustrations

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Turbine engine operators are familiar with damage to components due to dust-laden air in the compressor, but they are less aware that such damage can also occur to high temperature components, especially turbine rotor blades. Nevertheless, the frequency of occurrence of this type of damage as well as the related costs and effects on turbine performance are also of major concern. Author

N95-19675# Liburdi Engineering Ltd., Hamilton (Ontario).

PROTECTIVE COATINGS FOR COMPRESSOR GAS PATH COMPONENTS

D. R. NAGY, V. R. PARAMESWARAN (National Research Council of Canada, Ottawa, Ontario.), J. D. MACLEOD (National Research Council of Canada, Ottawa, Ontario.), and J. P. IMMARIGEON (National Research Council of Canada, Ottawa, Ontario.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 10 p (SEE N95-19653 05-07) Nov. 1994

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The blades and vanes in gas turbine compressors operating in dusty environments are prone to degradation by solid particle erosion, which causes surface roughening and changes in airfoil geometry. This results in decreased compressor performance, and higher specific fuel consumption, leading to significantly increased operational cost. Erosion damage is more prominent in flight engines without air inlet filter protection. Application of a thin ceramic titanium nitride (TiN) coating to improve the erosion

resistance of compressor airfoils was thoroughly investigated. Coatings were applied to engine hardware by a Reactive Ion Coating (RIC) process and optimized to produce a very adherent erosion resistant coating. Computer modeling of the erosion process occurring on coated and uncoated airfoils suggested that the operational life of the compressor can be enhanced by a factor of two. A complete set of compressor blades and vanes for an Allison T56 turboprop engine was coated for engine qualification tests. Laboratory tests showed that the thin coating had no significant influence on either the resonant frequency or the fatigue resistance of the blades and the instrumented engine tests confirmed that the performance was typical of overhauled engines, with no aerothermodynamic loss. Therefore, titanium nitride coatings are suitable for service and can be used on existing engines to improve the life of the compressors. Author

N95-19676# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry (France). Materials and Process Dept.
NEW TRENDS IN COATINGS DEVELOPMENTS FOR TURBINE BLADES: MATERIALS PROCESSING AND REPAIR
S. ALPERINE, R. MARTINOU, R. MEVREL (Office National d'Etudes et de Recherches Aeronautiques, Paris, France.), and J. P. HUCHIN (Sochata, Chatellerault, France.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 10 p (SEE N95-19653 05-07) Nov. 1994
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Turbine engines for aeronautic applications now have to face strenuous requirements concerning not only operating performances but also reliability and repairability. This evolution of the specifications induces important consequences regarding the choice and the design of turbine blade protective coatings. This paper presents several key features concerning the deposition techniques and the real-life behavior of such coatings: (1) complex aluminides well suited to the protection against high temperature oxidation and hot corrosion of directionally solidified nickel-base superalloy turbine blades; (2) ceramic coatings used as thermal barriers - they have to exhibit both high resistance to thermomechanical fatigue and adequate smoothness; (3) processing techniques for thermal barriers, including plasma spraying, electron beam physical vapor deposition and plasma enhanced chemical vapor deposition; and (4) blades and coatings repair techniques. Author

N95-19677# Interturbine Holding B.V., Lomm (Netherlands).
BRAZE REPAIR POSSIBILITIES FOR HOT SECTION GAS TURBINE PARTS
G. MARIJNISSEN and R. VANGESTEL (Elbar B.V., Lomm, Netherlands.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 5 p (SEE N95-19653 05-07) Nov. 1994
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Overlay braze repair is a good technique for restoring aircraft vanes and industrial blades and vanes. The negative effects of the intermetallic phase, formed during the overlay braze process, can be reduced in such a way that the mechanical properties - creep rupture, strength and ductility - can be achieved close to the properties of the base materials. The elimination of the negative effects can be achieved by a combination of careful selection of the chemistries of the repair materials and the application of the correct procedures for cleaning and heat cycle. Author

N95-19678# National Aerospace Lab., Amsterdam (Netherlands).
GAS TURBINE COMPRESSOR CORROSION AND EROSION IN WESTERN EUROPE
H. J. KOLKMAN *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 7 p (SEE N95-19653 05-07) Nov. 1994
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It is shown that for gas turbines in the West European environment: (1) during operation hygroscopic salts - notably ammonium sulphate (originating from manure) and sodium and magnesium chloride (from sea salt) - are deposited on compressor components and (2) during shutdowns these wet deposits acidify owing to the absorption of the air pollutants NO2 and SO2. The response of the compressor metals can be broadly categorized as follows. Different steels show different degrees of corrosion. Especially pitting corrosion can lead to component rejection and compressor disintegration. This necessitates frequent washing and/or corrosion resistant coatings. Modern cleaners are environmentally friendly and contain a corrosion inhibitor. The performance of cleaners and coatings is discussed. Nickel-based superalloys and titanium alloys are not prone to corrosion in compressor applications. In order to avoid problems these materials should be used even for secondary components. This is exemplified by a crash due to stress corrosion of a component costing only a few dollars. Compressor erosion as such is not a major problem in Western Europe. However, corrosion resistant coatings usually have a poor erosion resistance. Moreover, engine manufacturers and users prefer a general compressor coating for use in both corrosive and erosive environments. Developments with respect to compressor cleaners and coatings are discussed. Author

N95-19679# Turbomeca S.A. - Brevets Szydlowski, Bordes (France).
MULTILAYER ANTI-EROSION COATINGS [REVETEMENTS ANTI-EROSION MULTICOUCHES]
P. MONGE-CADET, F. PELLERIN, C. FARGES (Etablissement Technique Central de l'Armement, Arcueil, France.), D. RICKERBY (Rolls-Royce Ltd., Derby, England.), and E. QUESNEL (Nuclear Research Center of Grenoble, Grenoble, France.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 8 p (SEE N95-19653 05-07) Nov. 1994 In FRENCH
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Gas turbines for helicopters are prone to high degradations by abrasive particle ingestion when taking off, landing or during low altitude flights. Multilayer coatings have been developed to protect critical compressor components. After a presentation of the relevant parameters for conception and achievement of erosion resistant coatings, the most promising systems will be described. They are based on stacking arrangement of ductile layers (tungstene) and hard layers (solid solution of carbon or nitrogen into tungstene, titanium diboride). These multilayer coatings exhibit an erosion resistance improved by more than two orders of magnitude compared with that of uncoated Ti6Al4V alloy. Author

N95-19680# Turbine Support Europa, Tilburg (Netherlands).
HIGH VELOCITY OXYGEN FUEL SPRAYING OF EROSION AND WEAR RESISTANT COATINGS ON JET ENGINE PARTS
A. T. J. VERBEEK *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 10 p (SEE N95-19653 05-07) Nov. 1994
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High velocity oxygen fuel (HVOF) spraying is the most recent development in the field of thermal spraying. The importance of this technique for the repair and new part manufacturing of jet engine parts is rapidly increasing. The HVOF uses a supersonic oxygen-fuel flame to heat and accelerate the powder particles that form the coating. The high particle velocity results in a high density and a low porosity, a high bond strength, and a high macro and micro hardness of the coating. The high quality of the HVOF coatings makes it possible to use these coatings on high loaded, rotating parts in jet engines. This paper will highlight the use of HVOF processes to apply erosion resistant cermet coatings to high pressure compressor blades. These blades are exposed to severe erosion. Next to the D-gun process, HVOF spraying is the only nonproprietary technique that can be used to apply these high performance coatings. Also the use of the HVOF process to apply wear resistant coatings and superalloys to jet engine parts will be discussed. The difference between HVOF coatings and plasma sprayed coatings will be highlighted. During HVOF spraying, the parts are exposed to a high heat flow. Solutions to avoid overheating, especially of titanium parts, will be presented. Author

N95-19681# Centro Sviluppo Materiali S.p.A., Trento (Italy).
THERMAL TESTING OF HIGH PERFORMANCE THERMAL BARRIER COATINGS FOR TURBINE BLADES
L. BERTAMINI and A. DIGIANFRANCESCO (Centro Sviluppo Materiali S.p.A., Rome, Italy.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 11 p (SEE N95-19653 05-07) Nov. 1994
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A 350 micron thick 7 wt percent Y2O3-ZrO2 (7YSZ) ceramic Thermal Barrier Coating (TBC) was manufactured in an argon atmosphere and with a strictly controlled substrate temperature

on flat IN 600 samples and on IN 100 aircraft turbine blades. This new atmosphere and temperature controlled spraying (ATCS) allows the reduction of the residual stresses and an improvement in the microstructure and in the mechanical properties of the coating. The good performance of these new TBC's was assessed in thermal fatigue and in thermal shock tests carried out in air at 1100 C and at 1280 C respectively. The oxidation rate of the metal-ceramic interface was measured at 1100 C. Failure of the TBC's was induced only by the deterioration (like oxidation, cracking) of the uncoated parts of the samples, as testing temperature was too severe for the base metals. Spalling was thereafter driven by compressive stresses near the aluminum oxide layer at the metal-ceramic interface. The results of these tests underline the good quality of the ceramic coating manufactured by the new ATCS technology. Author

N95-19683*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
RESISTANCE OF SILICON NITRIDE TURBINE COMPONENTS TO EROSION AND HOT CORROSION/OXIDATION ATTACK
THOMAS E. STRANGMEN (Garrett Turbine Engine Co., Phoenix, AZ.) and DENNIS S. FOX *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 11 p (SEE N95-19653 05-07) Nov. 1994
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Silicon nitride turbine components are under intensive development by AlliedSignal to enable a new generation of higher power density auxiliary power systems. In order to be viable in the intended applications, silicon nitride turbine airfoils must be designed for survival in aggressive oxidizing combustion gas environments. Erosive and corrosive damage to ceramic airfoils from ingested sand and sea salt must be avoided. Recent engine test experience demonstrated that NT154 silicon nitride turbine vanes have exceptional resistance to sand erosion, relative to superalloys used in production engines. Similarly, NT154 silicon nitride has excellent resistance to oxidation in the temperature range of interest - up to 1400 C. Hot corrosion attack of superalloy gas turbine components is well documented. While hot corrosion from ingested sea salt will attack silicon nitride substantially less than the superalloys being replaced in initial engine applications, this degradation has the potential to limit component lives in advanced engine applications. Hot corrosion adversely affects the strength of silicon nitride in the 850 to 1300 C range. Since unacceptable reductions in strength must be rapidly identified and avoided, AlliedSignal and the NASA Lewis Research Center have pioneered the development of an environmental life prediction model for silicon nitride turbine components. Strength retention in flexure specimens following 1 to 3300 hour exposures to high temperature oxidation and hot corrosion has been measured and used to calibrate the life prediction model. Predicted component life is dependent upon engine design (stress, temperature, pressure, fuel/air ratio, gas velocity, and inlet air filtration), mission usage (fuel sulfur content, location (salt in air), and times at duty cycle power points), and material parameters. Preliminary analyses indicate that the hot corrosion resistance of NT154 silicon nitride is adequate for AlliedSignal's initial engine applications. Protective coatings and/or inlet air filtration may be required to achieve required ceramic component lives in more aggressive environments. Author

N95-19684# Naval Air Warfare Center, Trenton, NJ. Aircraft Div.
TESTING CONSIDERATIONS FOR MILITARY AIRCRAFT ENGINES IN CORROSIVE ENVIRONMENTS (A NAVY PERSPECTIVE)
FRANK T. CARROLL and DEBORAH R. PARISH *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 13 p (SEE N95-19653 05-07) Nov. 1994 Original contains color illustrations
(AGARD-CP-558) Copyright Avail: CASI HC A03/MF A03

This paper describes the considerations given to the testing of aircraft engines intended for use by the United States military (primarily the Navy) in potentially corrosive environments. The origins and intent of the Navy's full-scale corrosion susceptibility test are explored, and the evolution of the test from its early form to the present 1,200-hour program is described in detail. Sample results illustrating the effectiveness of the current test procedure are presented. Also noted are the activities currently underway to improve the test's effectiveness in the face of advancing engine and test equipment technologies. Author

08

AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

N92-23229*# Virginia Polytechnic Inst. and State Univ., Blacksburg, VA.
SENSITIVITY ANALYSIS OF DYNAMIC AEROELASTIC RESPONSES
RAKESH K. KAPANIA *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 12 p (SEE N92-23227 14-05) Feb. 1992
(Contract(s)/Grant(s): NAS1-18471)
(AGARD-R-784) Copyright Avail: CASI HC A03/MF A03

This paper summarizes ongoing research on the sensitivity analysis of dynamic aeroelastic response of wings. Two approaches are being used to express the unsteady aerodynamic loads: (1) the frequency-domain approach, and (2) the state-space approach. The frequency-domain approach is demonstrated on a three-dimensional box wing and the state-space domain approach is demonstrated on a simple two-dimensional sectional model. Three different methods are used to find the sensitivities: (1) a purely finite difference approach, (2) a semi-analytical approach in which an analytical expression is used for calculating the sensitivity of an eigenvalue of the complex valued aeroelastic matrix, however, the derivatives of the components of the matrix are obtained using finite difference, and (3) a semi-analytic approach that differs from (2) in the sense that the sensitivity of the aerodynamic matrix is now obtained analytically. A good agreement is seen between the three sets of results. For the two-dimensional sectional model the results for the sensitivities of the flutter speed with respect to the various parameters are obtained. Author

N92-23234# Oklahoma Univ., Norman, OK.
MULTIDISCIPLINARY OPTIMIZATION STUDIES USING ASTROS
ALFRED G. STRIZ (Oklahoma Univ., Norman.) and VIPPERLA B. VENKAYYA (Wright Research Development Center, Wright-Patterson AFB, OH.) *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 29 p (SEE N92-23227 14-05) Feb. 1992
(AGARD-R-784) Copyright Avail: CASI HC A03/MF A03

The influences of the structural and aerodynamic modeling on flutter analysis and multidisciplinary optimization of fully built-up finite element wing models in an aeroelastic environment are not yet well understood. Therefore, the dynamic aeroelastic and optimization capabilities in the Automated Structural Optimization System (ASTROS) were used to evaluate the flutter behavior and the behavior of structural optimization with flutter constraints of various representative fully built-up finite element wing models in subsonic and supersonic flow. ASTROS was here used as a tool to calculate flutter speeds and frequencies and to minimize the weight of these wing models in subsonic and supersonic flow under given flutter and frequency constraints to determine the effect that these modeling factors have. Author

N92-23238# British Aerospace Public Ltd. Co., Bristol (England). Airbus Div.

SIMULTANEOUS STRESS AND FLUTTER OPTIMIZATION FOR THE WING OF A TRANSPORT AIRCRAFT EQUIPPED WITH FOUR ENGINES

J. M. D. SNEE (British Aerospace Aircraft Group, Bristol (England).), H. ZIMMERMANN (Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).), D. SCHIERENBECK (Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).), and P. HEINZE (Deutsche Airbus G.m.b.H., Bremen, Germany, F.R.) *In* AGARD, Integrated Design Analysis and Optimisation of Aircraft Structures 12 p (SEE N92-23227 14-05) Feb. 1992

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The main objective of this work is to demonstrate the benefits of interdisciplinary optimization techniques to a modern aircraft design. The optimization is related to a four engine transport aircraft series equipped with a common wing. The series comprises of two aircraft differing in fuselage length by approximately 4 m but with the same maximum takeoff weight. Wing commonality in terms of optimization means that all the significant aeroelastic and static constraints are taken into account in order to achieve a weight optimized but also valid design proposal. In effect, this means that critical flutter situations of both aircraft types dependent on the fuel and load conditions as well as the dimensioning static load cases in combination with the stresses allowable must be introduced into a mathematical optimization model and the weight optimized solution must be sought with the aid of various optimization techniques. Author

N92-27956# National Aerospace Lab., Tokyo (Japan). Structural Mechanics Div.

NUMERICAL SIMULATION OF SHOCK-STALL FLUTTER OF AN AIRFOIL USING THE NAVIER-STOKES EQUATIONS

K. ISOGAI *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 12 p (SEE N92-27936 18-02) Mar. 1992

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

In order to confirm, qualitatively, the unusual flutter phenomenon, which has been observed experimentally for the high aspect ratio (non-tailored) forward swept wing model, as a shock-stall flutter, the aeroelastic response calculation of a two dimensional airfoil whose vibration characteristics are similar to those of the typical section of a forward swept wing, was performed by using the compressible Navier-Stokes equations as a flow solver. By the examination of the flow pattern, pressure distribution and the behavior of the unsteady aerodynamic forces during the diverging oscillation of the airfoil, it is concluded that this is a shock-stall flutter, in which the large scale shock-induced flow separation is playing the dominant role and that there is a mechanism of putting energy into the elastic system of the airfoil, leading to nearly a single degree of freedom flutter. Author

N92-27958# National Aerospace Lab., Amsterdam (Netherlands).

DEVELOPMENT OF A METHOD TO PREDICT TRANSONIC LIMIT CYCLE OSCILLATION CHARACTERISTICS OF FIGHTER AIRCRAFT

J. J. MEIJER (National Aerospace Lab., Amsterdam (Netherlands).) and A. M. CUNNINGHAM, JR. (General Dynamics Corp., Fort Worth, TX.) *In* AGARD, Transonic Unsteady Aerodynamics and Aeroelasticity 21 p (SEE N92-27936 18-02) Mar. 1992 Sponsored in part by AF and General Dynamics Corp.

(Contract(s)/Grant(s): NIVR-07801-N)

(AGARD-CP-507) Copyright Avail: CASI HC A03/MF A04

An analysis of steady wind tunnel data obtained for a fighter type aircraft indicated that shock-induced and trailing edge separation plays a dominant role in the development of Limit Cycle Oscillations (LCO) at transonic speeds. On this basis, a semi-empirical LCO prediction method is being developed which makes use of such steady wind tunnel data. The preliminary method was applied to several configurations and correctly identified those which have encountered LCO. The method has the potential for application early in the design process of new aircraft to determine and understand these nonlinear aeroelastic characteristics. The method is still being evaluated, and upgrading and refinements are expected from unsteady wind tunnel force and pressure measurements to be obtained from oscillating models as part of an extensive investigation into the aerodynamic nature of LCO. The method is described in its present form and the results of the latest predictions are compared with flight results and used to further assess various parametric effects. Author

N93-17617# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).

MULTIPLE-INLET CONFIGURATION FOR MISSILES WITH SKID-TO-TURN CONTROL MODE

W.-D. POHL and E.-O. KROHN (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Berlin, Germany) *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 13 p (SEE N93-17607 05-20) Sep. 1992

(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

For missiles with cartesian control mode a symmetrical configuration with four inlets is most common. The operation of a multiple inlet system is significantly influenced by the interaction of the coupled inlets. Inherent problems are discussed by means of a simplified model and windtunnel test results. First a configuration with four axisymmetrical inlets is presented. Different inlet geometries and the influence of an external boundary layer bleed are investigated in order to obtain an enlarged stable operation regime. Windtunnel tests of individual inlets and of four coupled inlets showed the effects of inlet matching and the resulting overall performance. Furthermore a configuration with four rectangular inlets is discussed. Problems and advantages of the conventional and the inverted integration mode are illustrated using wind tunnel test results. It is shown that the use of a pre-compression ramp is especially beneficial to the inlet matching of four inverted inlets. Author

N93-19915# British Aerospace Defence Ltd., Preston (England).

IN-FLIGHT STRUCTURAL MODE EXCITATION SYSTEM FOR FLUTTER TESTING

R. B. RAMSAY *In* AGARD, Flight Testing 20 p (SEE N93-19901 06-05) Oct. 1992

(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

A system for exciting the modes of vibration of an unstable digitally controlled fly-by-wire combat aircraft via the primary control actuators in order to extract flutter data is presented. The system has been developed on the Experimental Aircraft Program (EAP) to generate, within the Flight Control computers, frequency sweep and impulse excitation signals which are injected via the primary control actuators to the foreplane and wing trailing edge flaperons. The choice of surface, actuator amplitude input and symmetric or antisymmetric excitation is pilot selectable. The system will permit predefined waveforms, referred to as test routines, to be summed into the Flight Control System (FCS) actuation loops under cockpit control. Rig and aircraft ground response performance tests were performed on the foreplane and wing outboard trailing edge flaperon actuators as part of the qualification of the system. A flight test program of 15 flights measured aircraft responses due to the injection of frequency sweeps and impulses. Results are presented for the foreplane and the wing and a comparison made with predictions and previous flight flutter tests using bonker impulsive excitation. Operation of this system demonstrated the flexibility in being able to select the excitation type and input amplitudes, optimized to the aircraft configuration and flight condition, to extract high quality data, which is the key to successful flight flutter testing. Use of this system, particularly where structural limitations restrict the use of other types of excitation, offers great potential in reducing overall testing time for aircraft with a large number of stores, provided the system is designed to have flexibility in the choice of input available to the test engineer. Author

N93-19918# National Research Council of Canada, Ottawa (Ontario).

FLY-BY VOICE, A TECHNOLOGY DEMONSTRATION

J. MURRAY MORGAN and DAVID R. STARKS (Canadian Marconi Co. Ltd., Kanata, Ontario) *In* AGARD, Flight Testing 10 p (SEE N93-19901 06-05) Oct. 1992

(AGARD-CP-519) Copyright Avail: CASI HC A02/MF A04

A connected word speech recognizer was mounted in the Flight Research Laboratory's Bell 205 Airborne Simulator (variable stability helicopter) and used to generate direct voice control over the aircraft's trajectory. The purpose of this exercise was to demonstrate the feasibility of sufficiently accurate speech recognition in the helicopter cockpit environment to permit free use of the technology in this situation. It was not intended to postulate that primary flight control should be achieved by voice

command alone. Integration of the Speech Recognizer in the cockpit proved not to be a trivial task, it was necessary to investigate and correct various technical errors in the aircraft's audio system, to modify the machine's power conversion system significantly and to deal with both inductive and audio pick-up. To enable the aircraft to be controlled adequately by the inherently low frequency voice command it was necessary to design and implement a suite of advanced control systems which could blend and switch between themselves as needed without pilot intervention and without producing aircraft behaviors which would cause the pilot concern regarding the safety of his aircraft. This paper describes the processes involved in Speech Recognizer integration and control word system development and concludes that connected speech recognition is viable as a useful and realizable adjunct to the advanced helicopter cockpit. Author

N93-28851# Defense Advanced Research Projects Agency, Arlington, VA.

X-31 DEMONSTRATION OF INTEGRATED FLIGHT AND PROPULSION CONTROL FOR EFFECTIVE COMBAT AT EXTREME ANGLES OF ATTACK

MICHAEL S. FRANCIS, E. DEVERE HENDERSON (Spectra Research Systems, Inc., Arlington, VA.), ERWIN KUNZ (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany.), SID POWERS (Rockwell International Corp., El Segundo, CA.), and HELMUT RICHTER (Ministry of Defence, Germany.) *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 14 p (SEE N93-28850 11-54) Apr. 1993

(AGARD-CP-520) Copyright Avail: CASI HC A03/MF A03

The X-31 Program is providing new options for conducting and winning close-in air combat in the future. Through the exploitation of the key EFM technologies - high thrust-to-weight ratio, multi-axis thrust vectoring, integrated flight-propulsion controls coupled with a 'pilot friendly' vehicle interface - the X-31 is pioneering dynamic post stall flight for a variety of combat applications. The key challenge to effective control in this arena is a compatible and properly tuned pilot-vehicle combination. The program's emphasis on control, simplicity, carefree handling, and situational awareness issues should help assure that its key objectives will be met. Various aspecs of the X-31 Program are discussed.

Derived from text

N93-28869*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

FLIGHT EVALUATION OF A COMPUTER AIDED LOW-ALTITUDE HELICOPTER FLIGHT GUIDANCE SYSTEM

HARRY N. SWENSON, RAYMOND D. JONES (Army Avionics Research and Development Activity, Fort Monmouth, NJ.), and RAYMOND CLARK (Army Avionics Research and Development Activity, Fort Monmouth, NJ.) *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 11 p (SEE N93-28850 11-54) Apr. 1993

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The Flight Systems Development branch of the U.S. Army's Avionics Research and Development Activity (AVRADA) and NASA Ames Research Center have developed for flight testing a Computer Aided Low-Altitude Helicopter Flight (CALAHF) guidance system. The system includes a trajectory-generation algorithm which uses dynamic programming and a helmet-mounted display (HMD) presentation of a pathway-in-the-sky, a phantom aircraft, and flight-path vector/predictor guidance symbology. The trajectory-generation algorithm uses knowledge of the global mission requirements, a digital terrain map, aircraft performance capabilities, and precision navigation information to determine a trajectory between mission way points that seeks valleys to minimize threat exposure. This system was developed and evaluated through extensive use of piloted simulation and has demonstrated a 'pilot centered' concept of automated and integrated navigation and terrain mission planning flight guidance. This system has shown a significant improvement in pilot situational awareness, and mission effectiveness as well as a decrease in training and proficiency time required for a near terrain, nighttime, adverse weather system. AVRADA's NUH-60A STAR (Systems Testbed for Avionics Research) helicopter was specially modified, in house, for the flight evaluation of the CALAHF system. The near terrain trajectory generation algorithm runs on a multiprocessor flight computer. Global Positioning System (GPS) data are integrated with Inertial Navigation Unit (INU) data in the flight computer to provide a precise navigation solution. The near-terrain trajectory and the aircraft state information are passed to a Silicon Graphics computer to provide the graphical 'pilot centered' guidance, presented on a Honeywell Integrated Helmet And Display Sighting System (IHADSS). The system design, piloted simulation, and initial flight test results are presented. Author (revised)

N94-10424# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).

EXPERIMENTAL RESULTS IN AERODYNAMIC STABILITY AND CONTROL OF A TSTO CONFIGURATION

T. GOTTMANN and G. CUCINELLI *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 14 p (SEE N94-10421 01-02) Apr. 1993

(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

A Winged Launcher Configuration (WLC) in a Two Stage To Orbit (TSTO) version has to fly through a wide range of angles-of-attack and Mach numbers (roughly -3 deg is less than or equal to alpha is less than or equal to 20 deg and 0.2 is less than or equal to Ma is less than or equal to 7.0). This and the requirements for horizontal take-off and landing in Central Europe, and the special separation maneuver at a hypersonic Mach number, causes a wide range of new aerodynamic and aerothermodynamic problems. Especially the problem of stability and control is increased by the wide alpha-Mach range and possibly strong engine effects. The main tasks of the experimental investigations of a TSTO configuration are to establish a data base to support the whole design process of Winged Launcher Configurations, to provide a validation base for CFD codes and to understand the very complicated problems which dominate stability, control, and stage separation aerodynamics. A generic baseline configuration of a TSTO was developed at MBB (lower and upper stage), which satisfies all requirements so far. To be able to test this configuration in all occurring speed regimes, a titanium model (size 1:160) was manufactured with an acceptable size to fit into most wind tunnels for sub-, super-, and hypersonic Mach numbers, especially at DLR in Germany and FFA in Sweden. The main part of the presentation deals with trends of the TSTO configuration in aerodynamic stability and control over the entire Mach regime, showing that some aerodynamic characteristics change significantly with increasing Mach number. Because all aerodynamic forces and moments must be balanced by the engine or aerodynamic controls to obtain reasonable flight conditions, statements regarding absolute stability and control features cannot be set up within this investigation, but tendencies can be given. Major emphasis is placed on the flap efficiency at high Mach numbers which exhibits a strongly nonlinear behavior. The separation of the upper stage was investigated in a special test phase, which shows the enormous changes in longitudinal characteristics caused by interference effects in close proximities between upper and lower stage.

Author (revised)

N94-10426# Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.

CONTROL EFFECTIVENESS AT HYPERSONIC SPEEDS

J. L. STOLLERY, D. KUMAR, P. A. ATCLIFFE, and H. BABINSKY *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 10 p (SEE N94-10421 01-02) Apr. 1993

(AGARD-CP-514) Copyright Avail: CASI HC A02/MF A04

Two models equipped with trailing edge flaps were tested at a Mach number of 8.2. A simple flat plate model was used to understand how control effectiveness is influenced by transition, bluntness, and incidence, while a cropped-delta-wing spaceplane configuration has emphasized the important three-dimensional effects arising from the geometry chosen. Schlieren photographs were used to visualize the flow, and pressure measurements on the windward surface of the spaceplane model showed any regions of separation. Encapsulated liquid crystals were used to obtain an overall picture of the heat transfer distribution and to highlight the three-dimensional structure of the flow. Author (revised)

N94-11489# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
STABILITY IN AEROSPACE SYSTEMS [LA STABILITE DANS LES SYSTEMES AEROSPATIAUX]
Feb. 1993 233 p Workshop held in Toulouse, France, 23-25 Jun. 1992
(AGARD-R-789; ISBN-92-835-0702-9; AD-A266953) Copyright Avail: CASI HC A11/MF A03

This volume contains the 18 unclassified papers presented at the Guidance and Control Panel Workshop. The presented papers cover topics under the following headings: fundamental aspects of stability with examples; basic theoretical aspects and chaos; and applications of aerospace techniques. For individual titles, see N94-11490 through N94-11504.

N94-11491# Universite Catholique de Louvain (Belgium).
STABILITY ANALYSIS AND AEROSPACE VEHICLE DYNAMICS
PIERRE Y. WILLEMS *In* AGARD, Stability in Aerospace Systems 10 p (SEE N94-11489 01-08) Feb. 1993 Sponsored by Belgian State Science Policy Programming Office
(AGARD-R-789) Copyright Avail: CASI HC A02/MF A03

This paper presents stability analysis results which can be used to analyze the behavior of aerospace vehicles. A certain number of definitions are recalled. Liapunov stability criteria are given for autonomous systems described by ordinary differential equations and discrete-time equations. Particular attention is paid to the stability of mechanical systems around equilibrium configurations.
Derived from text

N94-11492# Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau (Germany).
ON NON-LINEAR LONGITUDINAL STABILITY OF AN AIRCRAFT IN A DIVE IN THE PRESENCE OF ATMOSPHERIC DISTURBANCES
L. M. B. C. CAMPOS (Instituto Superior Tecnico, Lisbon, Portugal.) and A. A. FONSECA (Instituto Superior Tecnico, Lisbon, Portugal.) *In* AGARD, Stability in Aerospace Systems 19 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

We consider the nonlinear longitudinal stability problem of aircraft starting a dive from an initial velocity far removed from the steady dive speeds: the aim is to find a pitch control law, which will keep the aircraft in a constant glide slope, compensating for the phugoid mode. The problem is extended to account for the presence of arbitrary atmospheric winds, e.g., windshears. The theoretical stability curves are compared with flight test data, obtained using the BAFR (Basic aircraft for flight research) in Portugal. The model includes a number of effects, and has also some restrictions, which do not affect its suitability for the present application: (1) it includes compensation of the phugoid, but not short-period, mode i.e., neglects rotational inertia; (2) it accounts for boundary-layer and induced drag, but not wave drag, i.e., applies at low Mach numbers, typical of approach to land; (3) it neglects lateral motion, but allows for non-linear effects on longitudinal motion; and (4) it leads to a free-flying control law, in stall free conditions, and in the absence of autopilot or active control. These additional effects would be relevant to other applications, and would require extension or modification of the present model.
Derived from text

N94-11494*# Cornell Univ., Ithaca, NY.
DYNAMICS AND CONTROL OF COHERENT STRUCTURES IN THE TURBULENT WALL LAYER: AN OVERVIEW
GAL BERKOOZ, PHILIP HOLMES, and JOHN LUMLEY *In* AGARD, Stability in Aerospace Systems 5 p (SEE N94-11489 01-08) Feb. 1993 Sponsored by NASA. Langley Research Center; AFOSR; ONR; and NSF
(AGARD-R-789) Copyright Avail: CASI HC A01/MF A03

We expand the velocity field in the vicinity of the wall in empirical eigenfunctions obtained from experiment. Truncating our system and using Galerkin projection, we obtain a closed set of non-linear ordinary differential equations with ten degrees of freedom. We find a rich dynamical behavior, including in particular a heteroclinic attracting orbit giving rise to intermittency. The intermittent jump from one attracting point to the other resembles in many respects the bursts observed in experiments. Specifically, the time between jumps and the duration of the jumps, is approximately that observed in a burst; the jump begins with the formation of a narrowed and intensified updraft, like the ejection phase of a burst, and is followed by a gentle, diffuse downdraft like the sweep phase of a burst. The magnitude of the Reynolds stress spike produced during a burst is limited by our truncation. The behavior is quite robust, much of it being due to the symmetries present (Aubry's group has examined dimensions up to 128 with persistence of the global behavior). We have examined eigenvalues and coefficients obtained from experiment, and from exact simulation, which differ in magnitude. Similar behavior is obtained in both cases; in the latter case, the heteroclinic orbits connect limit cycles instead of fixed points, corresponding to cross-stream waving of the streamwise rolls. The bifurcation diagram remains structurally similar, but somewhat distorted. The role of the pressure term is made clear - it triggers the intermittent jumps, which otherwise would occur at longer and longer intervals, as the system trajectory is attracted closer and closer to the heteroclinic cycle. The pressure term results in the jumps occurring at essentially random times, and the magnitude of the signal determines the average timing. Stretching of the wall region shows that the model is consistent with observations of polymer drag reduction. Change of the third order coefficients, corresponding to acceleration or deceleration of the mean flow, changes the heteroclinic cycles from attracting to repelling, increasing or decreasing the stability, in agreement with observations. The existence of fixed points is an artifact introduced by the projection; however, a decoupled model still displays the rich dynamics. Numerous assumptions made in Aubry et al. (1988) can now be proved exactly. Feeding back eigenfuncitons with the proper phase can delay the bursting, (the heteroclinic jump to the other fixed point), decreasing the drag. It is also possible to speed up the bursting, increasing mixing to control separation. Our approach is optimal for short time tracking in control.
Author

N94-11496# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NONLINEAR AND DYNAMIC ANALYSIS OF FLIGHT [ANALYSE NON LINEAIRE ET DYNAMIQUE DU VOL]
P. GUICHETEAU *In* AGARD, Stability in Aerospace Systems 12 p (SEE N94-11489 01-08) Feb. 1993 In FRENCH
(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

In a rigorous manner, aircraft motion can be described by a set of nonlinear differential equations, depending of parameters, associating the state vector (angle of attack, sideslip angle, speed ...) with the control vector (motivators) through flight dynamics equations, aerodynamic aircraft model, and flight control system. The communication presents some works which aim at a better understanding and at the precise prediction of aircraft behavior in particular flight phases for which classical linearized analysis of differential equations is insufficient or not valid.
Author

N94-11497# Wright Lab., Wright-Patterson AFB, OH.
DECOUPLING OF AIRCRAFT RESPONSES
DAVID J. MOORHOUSE *In* AGARD, Stability in Aerospace Systems 9 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A02/MF A03

The theory of aircraft stability is at least as old as powered flight. The original impetus was to design the configuration to have acceptable characteristics. Flight control technology was next applied to tailor, i.e. improve, the classical response characteristics: a yaw damper being a simple example. More recent flight control technology has provided the means to change the character of the aircraft response so that it no longer exhibits the classical behavior of a short period, a phugoid, a Dutch roll, a roll mode, and a spiral. With additional control effectors and the use of feedback there is an infinite number of ways to change the basic stability and response characteristics. Pilot preferences are also well established, however, so that care is needed in implementing any theoretical improvements. The technology exists to provide the pilot with the capability to individually control all six degrees of freedom. Obviously, a requirement for a pilot to integrate six different control effectors would be likely to increase his workload. In that sense, decoupling all six axes would be detrimental. Conversely, any unwanted coupling that can be eliminated should reduce the pilot task. The Wright Laboratory has had a series of flight demonstration programs that have evaluated new technologies in the most realistic tasks. First, an F-16 was provided

with the additional control effectors to allow independent control of all six degrees of freedom. A variety of control modes was mechanized, so that the pilot could evaluate both coupled and decoupled modes. Following a subjective in-flight assessment, a ground-based piloted simulation experiment was performed to evaluate all modes for both offensive and defensive combat use. Second, an F-15 was modified to facilitate precise landing in adverse conditions. A special short landing mode was implemented to feature decoupling of airspeed and glideslope responses plus the integrated coupling of direct lift and sideforce control. This paper presents results from both these programs to illustrate the benefits of either decoupling or new coupling of aircraft responses. Derived from text

N94-11499# Wright Lab., Wright-Patterson AFB, OH.
MODELING NONLINEAR AERODYNAMIC LOADS FOR AIRCRAFT STABILITY AND CONTROL ANALYSIS
JERRY E. JENKINS and JAMES H. MYATT *In* AGARD, Stability in Aerospace Systems 10 p (SEE N94-11489 01-08) Feb. 1993 Sponsored by AFOSR and Dept. of National Defence
(AGARD-R-789) Copyright Avail: CASI HC A02/MF A03

Results from systematic wind tunnel tests of the dynamic roll behavior of a 65 degree swept delta wing at moderate (15 to 35 degree) angles of attack are reviewed. These tests, conducted in both the IAR 2 x 3 m low-speed wind tunnel and the 7 x 10 ft SARL facility at WPAFB, included static, forced oscillation and free-to-roll experiments with flow visualization. Multiple stable trim points (attractors) for body-axis rolling motions and other hard-to-explain dynamic behavior were observed. These data are examined in light of the nonlinear indicial response theory advanced by Tobak and his colleagues. The current analysis shows that force and moment, free-to-roll motion, and flow visualization data all confirm the existence of 'critical states' with respect to the static roll angle. When these singularities are encountered in a dynamic situation, large and persistent transients are induced. Conventional means of representing the nonlinear force and moments in the equations of motion are shown to be inadequate in these cases. Alternative approaches based on simplification of the nonlinear indicial model are briefly discussed. Derived from text

N94-11501# Air Force Inst. of Tech., Wright-Patterson AFB, OH.
UTILIZING QUANTITATIVE FEEDBACK THEORY DESIGN TECHNIQUE FOR FLIGHT CONTROL SYSTEM
CONSTANTINE H. HOUPIS *In* AGARD, Stability in Aerospace Systems 10 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A02/MF A03

Quantitative feedback theory (QFT) has achieved the status as a very powerful design technique for the achievement of assigned performance tolerances over specific ranges of plant uncertainties without and with control effector failures. This paper presents a brief overview of QFT and its applications to advanced multi-input multi-output (MIMO) flight control systems. Desired performance over varied flight conditions may be achieved with fixed compensators (controllers), despite failures of effectors. QFT is the only design technique that has been able to make considerable progress in improving the design of an overall flight control system taking into account the man-in-the-loop specifications. Author

N94-11502# State Univ. of New York, Binghamton, NY. Dept. of Electrical Engineering.
ADAPTIVE RECONFIGURABLE FLIGHT CONTROLS FOR HIGH ANGLE OF ATTACK AIRCRAFT AGILITY
T. SADEGHI, M. TASCILLO, A. SIMONS, and K. LAI *In* AGARD, Stability in Aerospace Systems 13 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

Two control technologies have been developed and integrated towards the definition of an Integrated Flight Control for the year 2000 (IFC2000) aircraft. The control technologies considered for IFC2000 are flight control reconfiguration and post stall maneuvering. The reconfiguration technique allows an aircraft to utilize the inherent redundancy among its control effectors for maintaining aircraft's controllability after loss (or degradation in effectiveness) of one or more of its control effectors. The reconfiguration technique used in this paper consisted of redistribution of control signals after identification of a control effector failure (first stage adaptation). This technique is based on utilizing a pseudo-inverse algorithm and minimizing a performance index to redistribute pilot's commands to the remaining control effectors. Two control laws were developed for controlling the aircraft in the post stall region where the aircraft is flying at high angle of attack (HAOA) while allowing reconfiguration in the event of surface damage or actuator failure. A self-tuning adaptive control law was developed for parameter estimation and control gain tuning (second stage adaptation). The control law utilizes the Bierman's algorithm for estimating aircraft parameters, and a linear quadratic regulator for tuning the gains. A neural net control law was developed to account for nonlinearity, parameter uncertainties, and disturbances in the flight control system. The reconfiguration, adaptive, and neural net control laws have been partially integrated; the results are reported in this paper. Post-stall maneuvering is configuration sensitive requiring a high performance aircraft with relaxed static stability, thrust vectoring, and/or additional surfaces (such as canard). A generic high performance aircraft model was modified to incorporate thrust vectoring for generating pitch and yaw moments. A control structure was developed to fly the aircraft with high angle of attack at low speed. The control structure can track alpha, phi, and beta commands from pilot's longitudinal and lateral sticks and rudder pedal, respectively. The control laws were designed to give steady state tracking for fuselage pointing. Thrust vectoring was used to produce pitch and yaw moments at HAOA. The control signal distribution function of the control laws was modified to facilitate aircraft transition from and to post-stall region. Author

N94-11503*# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
TOWARD INTELLIGENT FLIGHT CONTROL
ROBERT F. STENGEL *In* AGARD, Stability in Aerospace Systems 22 p (SEE N94-11489 01-08) Feb. 1993 Sponsored in part by FAA
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(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

Flight control systems can benefit by being designed to emulate functions of natural intelligence. Intelligent control functions fall in three categories: declarative, procedural, and reflexive. Declarative actions involve decision-making, providing models for system monitoring, goal planning, and system/scenario identification. Procedural actions concern skilled behavior and have parallels in guidance, navigation, and adaptation. Reflexive actions are more-or-less spontaneous and are similar to inner-loop control and estimation. Intelligent flight control systems will contain a hierarchy of expert systems, procedural algorithms, and computational neural networks, each expanding on prior functions to improve mission capability to increase the reliability and safety of flight and to ease pilot workload. Author

N94-11504# Wright Lab., Wright-Patterson AFB, OH.
X-29: LONGITUDINAL INSTABILITY AT HIGH ANGLE-OF-ATTACK
LAWRENCE A. WALCHLI *In* AGARD, Stability in Aerospace Systems 13 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

Relaxed static stability (RSS) was chosen as one of the primary technologies to be flight demonstrated on the forward swept wing X-29 aircraft. Development experiences and performance benefits of this technology in the high angle-of-attack (AOA) regime of flight are described. Flight test results validate the X-29's wind tunnel database and the updated piloted simulation is used for parameter variations to thoroughly explore the potential performance of an aircraft with high levels of static instability. Author

N94-28028# McDonnell-Douglas Aerospace Information Services Co., Saint Louis, MO.

PNEUMATIC MANAGEMENT OF BLUNTED-FOREBODY FLOW ASYMMETRY FOR HIGH-ANGLE-OF-ATTACK DIRECTIONAL CONTROL

FREDERICK W. ROOS, CHARLES L. MAGNESS, and DANIEL V. BROWN *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 6 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

Low-speed experiments have been conducted to explore the effectiveness of combining nose bluntness, which suppresses the tendency toward flowfield asymmetry, and pneumatic flow-separation control, which triggers flow asymmetry, into a system of pneumatic side-force control for a slender forebody shape at high angles of attack (alpha). The basic forebody shape studied, a 20%-blunted, 3.5-caliber tangent ogive, developed no side force over the range 0 less than or = alpha less than or = 60 degrees. Slight blowing through either or two symmetrically positioned orifices at the blunt nose of the forebody produced a degree of flow asymmetry (and a corresponding side force) that depended on jet massflow rate within limits that varied with alpha, the specific jet configuration, and laminar vs. turbulent boundary-layer separation. Forward-blowing jets were found to be generally more effective that nets normal to the forebody surface in producing pneumatic side-force control. Derived from text

N94-29317# Societe de Fabrication d'Instruments de Mesure, Massy (France). Industries Groupe Avionique.

PERFORMING SPECIFICATIONS FOR COMPLEX SYSTEMS' SOFTWARE [SPECIFICATIONS EXECUTABLES DES LOGICIELS DES SYSTEMES COMPLEXES]

F. DELHAYE and D. PAQUOT *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 14 p (SEE N94-29315 08-61) Nov. 1993 In FRENCH
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

The role played by numerical technologies has increased with each generation of flight control systems. Most of the functions of these systems are now assumed by integrated software and to industrialize the production of these software systems is rapidly becoming a necessity. The SFIM Industries have created a system which can successfully address each phase of the life cycle. Helicopter operating is intrinsically complex and any redundancy in the control systems increases this complexity. To create specifications for such systems is difficult but it is critical, as errors in specifications are often detected in the final phases of development, resulting in costly corrections. It is thus necessary to verify the precision and the justification of the specifications as early as possible. Within its Research and Development activities in avionics, SFIM evaluated the specifications' techniques in the cycle of complex systems' development. Several techniques have been studied (structural analysis, synchronized languages, expert systems) and two of them were tested in experiments. These techniques made it possible to create and validate some of the specifications, with varying degrees of success. The positive aspect of these techniques was clearly shown, they are significant elements in the cost management program of complex systems' software. Author

N94-34613# Defence Research Agency, Farnborough, Hampshire (England). Aerodynamics and Propulsion Dept.

DYNAMIC TESTS TO DEMONSTRATE LATERAL CONTROL USING FOREBODY SUCTION ON LARGE SCALE MODELS IN THE DRA 24 FOOT WIND TUNNEL

GERALDINE F. EDWARDS, A. JEAN ROSS, EDWARD B. JEFFERIES, and CHARLES O. OLEARY *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 14 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

The concept of applying suction at the nose of forebodies at high angles of attack to control the vortex flow was tested in two dynamic wind-tunnel experiments on large scale versions of the Defence Research Agency (DRA) High Incidence Research Model (HIRM1) in the DRA 24ft wind tunnel. The first experiment with a HIRM1 wind tunnel model mounted on a free-to-yaw rig used an analog control system. The model was controlled at angles of attack of 28 degrees and 32.5 degrees by applying differential suction through small holes near the nose apex to minimize the error between demanded and measured angle of sideslip. The second experiment used a free-flight version of HIRM1 with a digital Departure Prevention System (DPS) which was flown successfully in previous experiments. A nose suction control law, designed to maintain roll about the wind axis, was added to the DPS. The model was mounted on a rig which allowed freedom in yaw, roll, and pitch, the tailplanes could move symmetrically and differentially, and the rudder was used to augment directional stability. The model could be flown at angles of attack up to about 30 degrees, with the suction control law active, but would diverge in yaw and roll if the suction was turned off.
Author (revised)

N94-34615# Bath Univ. (England). School of Mechanical Engineering.

YAW CONTROL BY TANGENTIAL FOREBODY BLOWING

N. J. WOOD and W. J. CROWTHER *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 10 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03

Aircraft yaw control at high angles of attack by tangential forebody blowing has been investigated experimentally. Tests were performed in the University of Bath 2.1 m X 2.5 m low speed wind tunnel using an approximately 6 percent scale generic combat aircraft model fitted with blowing slots in the nose cone. Six component strain gauge balance force and moment data was measured for angles of attack up to 90 degrees for various slot geometries and locations. The effect of slot azimuthal location is demonstrated and a slot stall phenomenon described. A geometry dependent forebody/wing flow-field coupling has been identified which can lead to unexpected yawing and rolling moments. The primary source of yawing moment is shown to be the enhanced area of attached flow on the blown side of the forebody rather than direct vortex influence. The optimum slot extent and location depend on the angle of attack range over which control is required. For regions where steady vortex asymmetry is present, slots near the apex of the forebody produce severe control reversals at low blowing rates which can be minimized by placing the slots away from the apex. For control in regions where the flow is dominated by periodic vortex shedding, long slots offer efficient control to 90 degree angle of attack. The most suitable compromise for wide range control would appear to be a short slot placed away from the apex of the forebody. Author (revised)

N94-34616# Defence Research Agency, Bedford (England).

CONTROL OF LEADING-EDGE SEPARATION ON A CAMBERED DELTA WING

P. R. ASHILL and G. L. RIDDLE *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 13 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

Wind tunnel studies of flows over a cambered delta wing of 60 degrees leading-edge sweep at low speed have shown that the flow separates on a forward part of the curved upper surface. Although not apparent in surface pressure distributions, this separation strongly influences the position of the onset of leading-edge separation. The present paper describes a wind-tunnel study into the use of sub boundary-layer vortex generators, in the form of thin wires, to control the flow along and toward the upper-surface separation line. The control is effective because it shifts the position of the onset of leading-edge separation downstream, ensuring increased leading-edge thrust, mainly through a reorganization of the separated flow further downstream. The flow mechanisms are described, as well as the effects of wire number. Multiple wires can provide a reduction of about 16% in the lift-dependent drag factor. The implications of the study for the subsonic flight characteristics of supersonic combat aircraft are described and suggest that the vortex generators offer genuine improvements in subsonic maneuver performance.
Author (revised)

N94-34618# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft Group.

X-31A CONTROL LAW DESIGN

H. BEH and G. HOFINGER *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 9 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03

Tbis paper presents an overview on the X-31A flight control law design philosophy and the technical realization of the design.

After an introduction to the FCS hardware configuration, the basic control law structure and the method used for feedback gain calculation are presented. Several elements, such as the feedforward path, gravity effect compensation, inertial and gyroscopic coupling compensation, and the pilot command system, are discussed in more detail. Simplified block diagrams of the basic flight control mode in the longitudinal and lateral/directional axis follow. Finally, the implementation of the thrust vectoring system including engagement and disengagement procedure is shown. Author (revised)

N94-34619# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Flugmechanik.
X-31A SYSTEM IDENTIFICATION APPLIED TO POST-STALL FLIGHT: AERODYNAMICS AND THRUST VECTORING
D. ROHLF, E. PLASTSCHKE, and S. WEISS *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 12 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

Flight testing of the X-31A post-stall experimental aircraft started in Oct. 1990. By the end of 1992, the X-31A flight regime had been expanded to 70 deg angle of attack, and a significant number of flight tests with dynamic post-stall maneuvers had been performed. Within the international 'Combined X-31A Flight Test Team,' DLR (the German Aerospace Research Establishment) contributes its system identification experience and capabilities to the determination of aerodynamic parameters and thrust vector control effectiveness from flight test data. After a brief description of the applied hardware and software, this paper presents recent results from flight test data compatibility checking. The identification models used for the separated evaluation of longitudinal and lateral-directional motion are introduced. This emphasizes the model reductions necessary for X-31A high angle of attack applications. Identification results of selected aerodynamic parameters are shown in comparison to wind-tunnel predictions. The identification of the X-31A thrust vector control effectiveness is addressed, and preliminary results are presented as well. An overview of future identification activities with respect to nonlinear/instationary effects in the high angle of attack regime is given. Author (revised)

N94-36329# Technische Univ., Munich (Germany). Inst. of Flight Mechanics and Flight Control.
IMPROVEMENT OF ENDURANCE PERFORMANCE BY PERIODIC OPTIMAL CONTROL OF VARIABLE CAMBER
G. SACHS and R. MEHLHORN *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 7 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A02/MF A03

Other than in classical theory, endurance cruise is considered as an optimal periodic control problem where the state and control variables change in a periodic manner. Variable camber is introduced as a further control in addition to angle of attack and thrust setting. By periodically varying camber in a coordinated process with the two other controls, it is possible to fully exploit its potential of improving the lift/drag ratio for increasing the endurance of aircraft. It is quantitatively shown which gain in endurance performance can be achieved. Results are presented for an idealized engine model showing no control rate limitations as well as for a realistic model with constraints on control rates imposed. The numerical values for the constraints are chosen such that only slow thrust changes are admitted. Author

N95-14448# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
LATERAL JET CONTROL FOR TACTICAL MISSILES
P. CHAMPIGNY and R. G. LACAU *In* AGARD, Missile Aerodynamics 57 p (SEE N95-14445 03-02) Jun. 1994
(AGARD-R-804) Copyright Avail: CASI HC A04/MF A03

The aim of this paper is to give a survey of lateral jets as control system of tactical missiles. The paper is divided into four parts. The first part gives a brief analysis of new control requirements pertaining to tactical missiles, presents the advantages of lateral jet control, and describes two types of applications for missiles designed and developed by Aerospatiale-Missiles. The first example relates to the ground/surface-to-air missile ASTER which has antimissile capability; the second example concerns the antitank missile ERYX. The second part presents in detail the phenomenological aspects of lateral jets and the influence of various flow parameters and missile geometry on control system performance. The third part describes some wind-tunnel testing problems. The fourth and last part is dedicated to computation for valuation and understanding of the aerodynamic interactions. Derived from text

N95-14900# Technische Univ., Brunswick (Germany). Inst. of Flight Guidance and Control.
TURBULENCE: ENGINEERING MODELS, AIRCRAFT RESPONSE
MANFRED SWOLINSKY *In* AGARD, Flight in an Adverse Environment 20 p (SEE N95-14893 03-03) Nov. 1994
(AGARD-LS-197) Copyright Avail: CASI HC A03/MF A02

This paper covers problems of flight in a turbulent atmosphere. A realistic simulation of aircraft behavior in turbulent air requires different engineering models. On one hand, this means a mathematical description of random turbulence or short scale gusts. For simple problems, a computation of the turbulence velocity vector only at the trajectory of the aircraft is sufficient. In cases of detailed investigations, the generation of a 3-dimensional spatial turbulence field is necessary. Additional real time requirements imply special approaches, such as the realization of a matrix wind model. On the other hand the description of the interaction between turbulence or short scale gusts and aircraft may require complex aerodynamic models especially if the gust scale and the aircraft scale are in the same order of magnitude. The presented multi point or lifting surface models consider the wind vector at several points along the wing span under real time constraints. Based on simulation results and flight test data, the dynamic aircraft response is discussed. Single gust effects are demonstrated by examples of cross flights through the updraft of a powerplant cooling tower. Author

N95-18597# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AIRCRAFT LOADS DUE TO TURBULENCE AND THEIR IMPACT ON DESIGN AND CERTIFICATION [EFFORTS AVION DUS A LA TURBULENCE ATMOSPHERIQUE ET LEURS IMPACTS SUR LA CONCEPTION ET LA CERTIFICATION]
Dec. 1994 93 p In ENGLISH and FRENCH Workshop held in Lillehammer, Norway, 5 May 1994
(AGARD-R-798; ISBN-92-836-0002-9) Copyright Avail: CASI HC A05/MF A01

The AGARD Structures and Materials Panel has always been heavily involved in the field of the effects of atmospheric disturbances on the behavior of aircraft. The Panel organized a Workshop on the theme 'Aircraft Loads due to Turbulence and their Impact on Design and Certification'. This Workshop was held on 5 May 1994. This document reproduces the papers presented. For individual titles, see N95-18598 through N95-18605.

N95-18598# British Aerospace Airbus Ltd., Bristol (England).
THE IMPACT OF NON-LINEAR FLIGHT CONTROL SYSTEMS ON THE PREDICTION OF AIRCRAFT LOADS DUE TO TURBULENCE
R. M. WARMAN *In* AGARD, Aircraft Loads due to Turbulence and their Impact on Design and Certification 8 p (SEE N95-18597 05-08) Dec. 1994
(AGARD-R-798) Copyright Avail: CASI HC A02/MF A01

During the past ten years the extensive use of electronic flight control systems has introduced a high level of non-linearity, to the behavior of civil transport aircraft, in response to both pilot inputs and external influences such as turbulence. These systems that control, protect, and, in some instances, alleviate the loads experienced by the aircraft have had a significant impact on the prediction of aircraft loads. There is an increasing need both to model control system non-linearity to avoid designing control systems that degrade structural performance, and to demonstrate the effectiveness of alleviation systems for aircraft certification. The introduction of non-linear flight control systems presents little problem when using time-based simulations to predict aircraft loads due to discrete gusts. Frequency domain, Power-Spectral Density (PSD), analysis used to predict aircraft loads due to Continuous Turbulence (CT), however, is severely restrictive, requiring a linear mathematical model of both the aircraft and control systems. Over the past ten-to-fifteen years various analysis techniques have been

developed that provide time-based interpretations of the CT atmosphere and, therefore, means by which loads due to CT can be predicted for aircraft with non-linear flight control systems. Recent involvement in the design of Airbus aircraft has led to British Aerospace Airbus Limited taking an active role in both developing and using these non-linear analysis techniques. By drawing on experience gained during the design of recent Airbus aircraft, the impact of non-inear flight control systems on the prediction of aircraft loads due to turbulence is discussed.
Author

N95-18600# Deutsche Airbus G.m.b.H., Hamburg (Germany). Structural Dynamics.
TREATMENT OF NON-LINEAR SYSTEMS BY TIMEPLANE-TRANSFORMED CT METHODS: THE SPECTRAL GUST METHOD
H. LUSEBRINK and J. BRINK-SPALINK *In* AGARD, Aircraft Loads due to Turbulence and their Impact on Design and Certification 8 p (SEE N95-18597 05-08) Dec. 1994
(AGARD-R-798) Copyright Avail: CASI HC A02/MF A01

The present paper discusses the problems which occur when PSD/Continuous Turbulence (C.T.) gust methods, originally developed for linear dynamic gust analysis in the frequency plane, are applied to modern transport A/C with flight control systems, containing a variety of nonlinearities for signal shaping. Power spectral density (PSD) gust velocity intensities are defined by the von Karman power spectrum in the frequency plane, scaled by the design gust intensity U(sub sigma) (RMS). This definition of gust in the frequency plane causes the basic problems for nonlinear dynamic analysis, in contrary to the timeplane defined Tuned Discrete Gusts. Discrete Gust calculations show that aircraft nonlinearities cannot be neglected. To treat nonlinearities for C.T. there are basically three approaches (apart from linearization methods): (1) (SSB) Stochastic Simulation Based Methods (timeplane stochastic simulation), usually in combination with exceedance rate based design load definition; (2) MFB) Matched Filter Based Methods ('Worst Case Gusts'): for each load station, a search within a class of shape functions of prescribed 'spectral energy' is necessary to find that shape giving the highest load; and (3) (SG) Spectral Gust Method: uses discrete gusts having exactly the von karman spectrum, and computes the energy norm of the loadtime history. A practical method for nonlinear C.T. method should have the following characteristics: give loads consistent to existing requirements (for linear aircraft); give correlated (balanced) loads; and be straight-forward and economical, when applied for a large number of design cases to be calculated. Since the SSB methods need long simulation times and give no balanced loads (together with exceedance rate counting), and the MFB methods are very expensive, the present paper proposes the SG method. It needs only one step to derive design loads, is consistent to Design Envelope Analysis and provides correlated loads.
Author

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RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tubes; and aircraft engine test stands.

N92-28523# Federal Ministry for Defence, Bonn (Germany). Armaments Technology Directorate.
OPPORTUNITIES FOR FLIGHT SIMULATION TO IMPROVE OPERATIONAL EFFECTIVENESS
J. HEYDEN *In* AGARD, Piloted Simulation Effectiveness 15 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

The keynote address gives an overview over the opportunities of piloted simulation for the development of aircraft and for the training of aircrews to operate the aircraft. Based on the military flight mission requirements some critical issues of peacetime military operations in Europe are discussed and the resulting opportunities for application of flight simulation in development and training are presented. The address concludes on recommendations for piloted simulation.
Author

N92-28524# Wright Lab., Wright-Patterson AFB, OH. Flight Dynamics Directorate.
PILOTED SIMULATION EFFECTIVENESS DEVELOPMENT APPLICATIONS AND LIMITATIONS
RICHARD A. BOROWSKI *In* AGARD, Piloted Simulation Effectiveness 3 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A01/MF A03

The author of this brief note begins by describing how flight simulators were first developed, and the reasons that brought about this research. The remainder of his paper is a survey of some simulation systems used in the U.S. with the recognition that similar and in some cases superior systems exist elsewhere. Concentration is placed on simulators run by the government, the military, and NASA.
H.A.

N92-28525# Air Force Flight Test Center, Edwards AFB, CA.
UTILITY OF GROUND SIMULATION IN FLIGHT CONTROL PROBLEM IDENTIFICATION, SOLUTION DEVELOPMENT, AND VERIFICATION
K. L. KELLER, D. B. JANZEN, and A. A. ASAY *In* AGARD, Piloted Simulation Effectiveness 8 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A02/MF A03

The Air Force Flight Test Center (AFFTC) Flying Qualities Simulator is consistently used prior to and in conjunction with flight test to identify aircraft flight control problems and also to develop, test, and validate solutions to these problems. The subject of this paper is an example of how ground simulation was vital in developing an effective software modification to eliminate a potentially dangerous aircraft flight control anomaly. Through simulation, an in flight uncommanded pitch oscillation incident was investigated and the source of the problem was identified. A potential solution was tested and validated by utilizing the simulator prior to flight test. Additional benefits were gained due to simulation studies. The project pilots were able to practice test maneuvers and emergency procedures essential to the flight test program. The preliminary work accomplished by ground simulation correctly predicted the effectiveness of the software modifications and ensured the success of an efficient and valid flight test program.
Author

N92-28526# Aerospatiale, Toulouse (France).
FLIGHT SIMULATION AND DIGITAL FLIGHT CONTROLS
D. CHATRENET *In* AGARD, Piloted Simulation Effectiveness 4 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A01/MF A03

The A-320 is the first civil airliner to make extensive use of digital flight controls. Despite previous experience with this technology, developing this system quickly has proven a challenge. Flight simulation with a high degree of fidelity has played a key role in flight control development. Simulation has also complemented the flight testing of the A-320-200. Digital flight control has moved the critical areas from aerodynamic model accuracy to flight control system representation exactness. Simulator acceptance procedures had also to be adapted to address the case of closed loop controlled aircraft correctly.
Author

N92-28527# McDonnell-Douglas Helicopter Co., Mesa, AZ. Flight Mechanics/Performance Dept.
THE APPLICATION OF FLIGHT SIMULATION MODELS IN SUPPORT OF ROTORCRAFT DESIGN AND DEVELOPMENT
P. SHANTHAKUMARAN *In* AGARD, Piloted Simulation Effectiveness 28 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

McDonnell Douglas Helicopter Company's overall approach to design development and flight evaluation through flight simulation models is presented. Flight simulation model description, validation against flight test data bases, and applications for rotorcraft design and development, are presented. Specific model refinements for each application are emphasized. Examples include power-off emergency landing, empennage design, maneuver envelope expansion, engine-airframe integration, and manned simulations.
Author

N92-28528# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Helicopter Div.
EXPERIENCE WITH PILOTED SIMULATION IN THE DEVELOPMENT OF HELICOPTERS
M. OBERMAYER, K. KAMPA, W. DOEHNEL, and A. FAULKNER *In* AGARD, Piloted Simulation Effectiveness 11 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

Based on examples from several projects this paper reflects MBB's experience with applicability, limitations, acceptance, and effectiveness of helicopter simulation. Some of the key points are the objective and subjective validation of a simulator and various factors, which influence the acceptance by pilots. In this context it is very important to make a trade-off between simulator sophistication and required results. Other aspects of simulation effectiveness include evaluation and training of critical flight conditions prior to flight tests as well as involving the customer from early concept studies up to full mission simulations, which gives him more influence on the design and leads to better identification with the product. Author

N92-28532# National Aerospace Lab., Amsterdam (Netherlands).
AIRCRAFT SIMULATION AND PILOT PROFICIENCY: FROM SURROGATE FLYING TOWARDS EFFECTIVE TRAINING
P. G. A. M. JORNA (National Aerospace Lab., Amsterdam (Netherlands).), E. R. A. VANKLEEF (Royal Netherlands Air Force, The Hague.), and W. P. DEBOER *In* AGARD, Piloted Simulation Effectiveness 8 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A02/MF A03

Simulators are currently built as simple system 'look-a-likes' and a structured or experimentally validated approach to their use and implementation as part of a comprehensive training system is lacking. This is one reason why their use in training was not always as successful as expected. This paper reviews some experiences with the application of simulators in military flight training and it reports research strategies like the development of objective performance measures in support of validation trials and future simulator development. It is proposed to prototype simulator concepts before implementing them and relevant research initiatives in this area are reviewed. Author

N92-28533# CAE Electronics Ltd., Montreal (Quebec). Tactical Systems Div.
THE USE OF A DEDICATED TESTBED TO EVALUATE SIMULATOR TRAINING EFFECTIVENESS
DAVID KURTS (CAE Electronics Ltd., Montreal (Quebec).) and CHARLES GAINER (Army Research Inst. Aviation Research and Development Activity, Fort Rucker, AL.) *In* AGARD, Piloted Simulation Effectiveness 9 p (SEE N92-28522 19-01) Feb. 1992
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The Simulator Complexity Test Bed (SCTB) is being produced for the U. S. Army Research Institute Aviation Research and Development Activity (ARIARDA) to specifically address the question of the level of simulation fidelity required to ensure adequate transfer of training in a tactical helicopter simulator environment. This paper presents the objectives of the SCTB, the hardware and software architecture designed to facilitate these goals, and presents examples of some typical research that will be conducted. The simulator is based on the Apache AH-64A attack helicopter using aircraft parts and simulated avionics to provide a realistic replica of the pilot and copilot gunner positions. Author

N92-28535# Air Force Flight Test Center, Edwards AFB, CA. Test and Evaluation Simulator.
USE OF SIMULATION IN THE USAF TEST PILOT SCHOOL CURRICULUM
DANIEL P. RINGENBACH (NSI Technology Services Corp., Greenbelt, MD.), STEVEN E. LOUTON (NSI Technology Services Corp., Research Triangle Park, NC.), and DANIEL GLEASON *In* AGARD, Piloted Simulation Effectiveness 7 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A02/MF A03

The six degree-of-freedom, real time, Test Pilot School (TPS) simulator at the Test and Evaluation Mission Simulator (TEMS) of the Air Force Flight Test Center (AFFTC) is an invaluable and versatile tool used by the TPS. It is an effective learning tool providing positive reinforcement on basic aircraft dynamics taught in the classroom and an efficient evaluation tool for flight control systems designed by the students. Author

N92-28536# Alenia, Turin (Italy). Flight Simulation Center.
AM-X FLIGHT SIMULATOR FROM ENGINEERING TOOL TO TRAINING DEVICE
A. ARMANDO, P. CASTOLDI, and F. FASSI *In* AGARD, Piloted Simulation Effectiveness 12 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

Effectiveness of Flight Simulation with pilot-in-the-loop can be intended rather differently depending on the context in which the simulation activities are carried out, namely in the two traditional areas of Research & Development (R&D) and Training. In the latter case, effectiveness can be considered the amount of training a simulator is able to transfer per time unit, while in the case of R&D simulation its effectiveness is related to the amount of confidence engineers can gain in the prediction of an airborne system behavior before releasing it to the real flight. Pursuing the maximization of effectiveness in these two different contexts leads to different approaches in applying simulation methodologies. This paper will show to what extent a simulation facility created and continuously improved to support the development of a new attack aircraft, the AM-X, was finally capable of training operational pilots during the conversion to that aircraft. Author

N92-28537# Sikorsky Aircraft, Stratford, CT.
FULL MISSION SIMULATION: A VIEW INTO THE FUTURE
MICHAEL J. FERRANTI and STEPHEN H. SILDER, JR. *In* AGARD, Piloted Simulation Effectiveness 10 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A02/MF A03

The use of engineering simulation as a design support tool is becoming more prevalent in assisting design engineers in prototyping new concepts in advanced integrated helicopters. The primary goal in using full mission simulation as a risk reduction tool is that it can provide significant insight into critical design areas. In this capacity, it allows the research engineer the means to review critical design issues and assess areas of high risk associated with air vehicle design. The use of the Engineering Development Full Mission Flight Simulator (EDFMFS) will allow the design engineers the opportunity to view the future performance of the design air vehicle. This includes areas of both aerodynamic and operational suitability. The use of representative flight simulators will allow major design issues to be resolved with a significant reduction in the cost normally associated with developmental flight testing. The performance of flight control laws and cockpit design can be evaluated in the safe and secure environment of the simulator before actual flight test. In this regard, the capabilities of EDFMFS's have shown themselves to be an outstanding tool in evaluating advanced design aircraft during the initial design phase. Today's use of statistical and multivarient analysis techniques provides the designers with a real time quantitative capability to collect and analyze data, thus, reducing the risk associated with new product development. The methodologies used that provide the designer and pilots with the unique opportunity to evaluate different aircraft configurations in the Full Mission Flight Simulator before the design is concluded are identified. Author

N92-28538# Wright Lab., Wright-Patterson AFB, OH.
FULL MISSION SIMULATION FOR RESEARCH AND DEVELOPMENT OF AIR COMBAT FLIGHT AND ATTACK MANAGEMENT SYSTEMS
DANIEL G. GODDARD and JAMES M. ZEH *In* AGARD, Piloted Simulation Effectiveness 13 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

A description is presented of the analysis approach for an advanced development program using a realtime, pilot-in-the-loop air combat simulation. The program is developing and demonstrating advanced onboard flight and attack management algorithms to assist the pilot when outnumbered in air-to-air combat. A highly flexible simulation architecture allows hosting the flight test computer code in general purpose simulation computers. The simulator cockpit stations are modified to emulate the advanced pilot vehicle interface. A data collection and analysis approach is

described which isolates and measures the effects of the various systems making up the advanced fighter concept. Author

N92-28539# CAE Electronics Ltd., Saint Laurent (Quebec).
THE EVALUATION OF SIMULATOR EFFECTIVENESS FOR THE TRAINING OF HIGH SPEED, LOW LEVEL, TACTICAL FLIGHT OPERATIONS
ANDREW MORRIS (CAE Electronics Ltd., Montreal (Quebec).) and PAUL E. VANHEMEL (CAE-Link Corp., Alexandria, VA.) *In* AGARD, Piloted Simulation Effectiveness 11 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

The German Government has initiated a three phase program to evaluate the use of an improved simulator for the Tornado aircraft. In the first phase of this program computer aided engineering (CAE) has built a prototype simulator, referred to as the Evaluation Unit (EU). The improvements in the EU consist of visual system upgrades to provide a CAE Fiber-Optic Helmet Mounted Display (FOHMD) for the pilot and weapon system officer (WSO), with imagery from an Evans & Sutherland ESIG-1000 image generator, as well as a six-degree of freedom (DOF) motion system. The EU was installed at CAE Electronics GmbH in Stolberg, Germany. Military and industrial representatives are conducting an evaluation of the upgraded simulator to assess its capability to provide high speed, low level, tactical flight operations training capability. A factorial analysis of variance (ANOVA) design is being used to objectively assess recorded performance data and subjective impressions data collected during simulator flights by military crews from the German Air Force and Navy. Author

N92-28540# Ministry of Defence, London (England).
HARRIER GR MK 5/7 MISSION SIMULATORS FOR THE ROYAL AIR FORCE
B. R. CLIFFORD (Ministry of Defence, London (England).) and P. JACKSON (Link-Miles, Lancing, England) *In* AGARD, Piloted Simulation Effectiveness 6 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A02/MF A03

IN 1985, in anticipation of the phased replacement of the Harrier GR MK 3 by the Harrier GR MK 5, the UK version of the AV8B, the UK Air Staff issued a requirement for two mission simulators capable of fulfilling a comprehensive pilot training and evaluation task. It identified the need for simulators which would provide a wide range of psycho-physical cues with accurate flight and systems simulation, integrated with a high resolution, wide field-of-view visual system compatible with the Harrier's operational roles and inherent speed and agility. It became apparent that this would require the utilization of new technology, particularly in the area of head and eye-slaved visual displays; studies within the MoD confirm this and conclude that although innovative, the application of such technology was feasible. Some of the background and selection process are reviewed, and the mission simulators selected to meet the Royal Air Force's training needs are briefly described.
Author

N92-28541# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany).
DEVELOPMENT AND EVALUATION OF AN ATTACK AND MANEUVERING SYSTEM WITH COMBAT DEVELOPMENT SIMULATORS AS MAIN DEVELOPMENT TOOL
HERBERT EIBL, HANS-GUENTER OFFENBECK, and HANS W. PONGRATZ *In* AGARD, Piloted Simulation Effectiveness 17 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

As a result of conceptual design work on future fighter aircraft and of future air/air weapons it was concluded that in future air/air combat, especially in the beyond visual range (BVR) scenario, a pilot has to be supported by means of intelligent onboard processing equipment in order to fulfill his most demanding tasks by fully exploiting the weapon system capabilities. An integrated fire and tactical flight director control system was developed for the entire air combat arena by DASA MBB's Military Aircraft Division in its manned simulator facility. A description of the developed system and the used simulator facility is given. As a first step to verify this development, the Attack and Maneuvering System (AMS) for the BVR-air combat was successfully evaluated by the German Air Force in a large scale manned realtime simulation study. It was demonstrated that such a system can significantly improve the combat effectiveness of a modern fighter aircraft in the BVR-scenario by a factor of up to 6. Author

N92-28542# Naval Air Test Center, Patuxent River, MD. Rotary Wing Aircraft Test Directorate.
SHIPBOARD MISSION TRAINING EFFECTIVENESS OF THE NAVAL AIR TEST CENTER'S V-22 GOVERNMENT TEST PILOT TRAINER
G. VANDERVLIET, C. MILLER, and P. CROISETIERE *In* AGARD, Piloted Simulation Effectiveness 12 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

Initial shipboard compatibility tests of the V-22 Osprey VSTOL tiltrotor aircraft were conducted aboard the USS Wasp (LHD-1) on 4-8 Dec. 1990. Pilot training and engineering analysis for the first shipboard launches and recoveries of the V-22 Osprey aircraft were conducted in the V-22 simulator at the Naval Air Test Center. During these sessions, workload data was recorded and the pilots made comments regarding the quality of the training. Quantitative comparisons of time history data were made using power spectral densities, averages, and maximum attained values. Qualitative comments were compared to the remarks made after the actual at-sea tests. Conclusions are drawn concerning the effectiveness of the training, and suggestions for future improvements are made. Author

N92-28543# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
USE OF A RESEARCH SIMULATOR FOR THE DEVELOPMENT OF NEW CONCEPTS OF FLIGHT CONTROL [UTILISATION D'UN SIMULATEUR DE RECHERCHE POUR LE DEVELOPPEMENT DE NOUVEAUX CONCEPTS DE COMMANDES DE VOL]
PH. GUICHETEAU *In* AGARD, Piloted Simulation Effectiveness 11 p (SEE N92-28522 19-01) Feb. 1992 In FRENCH; ENGLISH summary
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

Several studies performed at ONERA have shown the usefulness of testing the behavior of the whole aircraft with the pilot in the loop by using a research flight simulator as soon as the preliminary design of new FCE for future aircraft is undertaken. The communication presents three conceptual studies related to mission oriented control systems which were performed at ONERA's research flight facility. The description of the conceptual phase of each of these studies and, for two of them, of their further validation on full flight simulators allows a conclusion about the complementary roles of research and full flight simulators.
Author

N92-28544# Dassault-Breguet Aviation, Saint-Cloud (France).
THE ROLE OF SIMULATION FOR THE STUDY OF APIS (PILOTING SUPPORT BY SYNTHETIC IMAGERY) [LE ROLE DE LA SIMULATION POUR L'ETUDE APIS (AIDE AU PILOTAGE PAR IMAGERIE SYNTHETIQUE)]
PIERRE LARROQUE, PIERRE PAGNIEZ, and ROLAND MIGINIAC *In* AGARD, Piloted Simulation Effectiveness 12 p (SEE N92-28522 19-01) Feb. 1992 In FRENCH
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

This report presents different methods of simulation used at Dassault Aviation for the APIS (pilot support by synthetic imagery) study. The aim of this study was to define man-machine concepts for synthetic imagery derived from onboard information and updated in flight. The imagery system provides the pilot with a comprehension and decision tool that can be used for any flight conditions (low altitude, poor visibility...) and tactical conditions. This document describes: (1) the methods used to produce static images from needs analysis, enabling a preliminary selection of acceptable images; (2) the use of workstations to generate and pilot in real time the solutions retained and to improve the representations; (3) interfacing workstations with a real-time processor and a RAFALE type simulation cabin, permitting manual or automatic execution of a 3-D trajectory in a simple scenario and used after evaluation by 10 pilots; (4) scenarios retained and results obtained as a result of these evaluations; and (5) follow up future spinoffs for the engineering of Dassault fighter aircraft.
Transl. by L.B.

N92-28545*# Systems Technology, Inc., Hawthorne, CA.
THE USE OF GROUND BASED SIMULATION FOR HANDLING QUALITIES RESEARCH: A NEW ASSESSMENT
DAVID G. MITCHELL (Systems Technology, Inc., Hawthorne, CA.), ROGER H. HOH (Hoh Aeronautics, Inc., Lomita, CA.), ADOLPH ATENCIO, JR. (Army Aviation Systems Command, Moffett Field, CA.), and DAVID L. KEY (Army Aviation Systems Command, Moffett Field, CA.) *In* AGARD, Piloted Simulation Effectiveness 14 p (SEE N92-28522 19-01) Feb. 1992
(Contract(s)/Grant(s): NAS2-13127)
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

A study was conducted on the NASA Ames Research Center's Vertical Motion Simulator to determine the effects of simulator characteristics on perceived handling characteristics. Differences in pilot opinion were found as the visual and motion parameters were changed, reflecting a change in the pilots' perceptions of handling qualities, rather than changes in the aircraft model itself. The results indicate a need for tailoring the motion without dynamics to suit the task, with reduced washouts for precision maneuvering as compared to aggressive maneuvering. Visual delay data are inconclusive, but suggest that it may be better to allow some time delay in the visual path to minimize the mismatch between vision and motion, rather than eliminate the visual delay entirely through lead compensation. The simulation results are compared with ratings from a similar in-flight simulation experiment. Author

N92-28546# Defence Research Agency, Bedford (England). Flight Systems Dept.
INITIAL VALIDATION OF A R/D SIMULATOR WITH LARGE AMPLITUDE MOTION
A. D. WHITE, J. R. HALL, and B. N. TOMLINSON *In* AGARD, Piloted Simulation Effectiveness 24 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

The Advanced Flight Simulator (AFS) Complex at the Defense Research Agency (DRA) at Bedford was enhanced by the addition of a large displacement motion platform and a three channel Computer Generated Image (CGI) outside world visual system. The trial described here was the first in a series of trials aimed at validating the AFS in its present configuration and in particular at demonstrating its ability to address a wide variety of vehicle handling qualities with a high degree of fidelity and user confidence. It included a direct comparison between the ground based AFS and the Calspan Learjet in-flight simulator. The comparison between the AFS and Learjet involved three pilots flying the same offset approach landing tasks using the same aircraft model in both the AFS and in flight. The lateral handling qualities were varied by adjusting the time constant of a filter in the pilot's roll control loop. Pilot comments, handling quality, and PIO ratings indicate that the AFS reproduces the lateral handling qualities and roll PIO tendencies of the Learjet in-flight simulator with high fidelity. The degradation in handling qualities and increase in PIO tendencies with increasing filter time constant were clearly revealed in both the AFS and Learjet. The importance of good platform motion cueing and task design when evaluating handling qualities was also demonstrated. Author

N92-28547# Deutsche Airbus G.m.b.H., Hamburg (Germany).
USE OF A VIRTUAL COCKPIT FOR THE DEVELOPMENT OF A FUTURE TRANSPORT AIRCRAFT
DIETER KRICKE and WILFRIED QUELLMANN *In* AGARD, Piloted Simulation Effectiveness 10 p (SEE N92-28522 19-01) Feb. 1992 Sponsored in part by BMFT and Council of the European Community
(AGARD-CP-513) Copyright Avail: CASI HC A02/MF A03

A development tool called the 'visual cockpit' is discussed. A comparison of civil and military transport aircraft development shows a significant technology gap on the military tactical transport side during the last 30 years. Therefore, it seems very beneficial to consider a 'dual use' of well-proven 'civil technologies' for military applications. Specific military transport missions require aircraft capabilities, some of which are quite new and therefore challenging for transport aircraft (e.g. low level flight profiles in night and poor visibility conditions). The demonstration of the feasibility and an evaluation of technical solutions imply the need for suitable development tools. The Virtual Cockpit is explained in terms of its components (hardware/software), features, and capabilities. A major field of investigation in this context is the aircraft systems' central control and monitoring. Author

N92-28548# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Flugmechanik.
THE ROLE OF SYSTEMS SIMULATION FOR THE DEVELOPMENT AND QUALIFICATION OF ATTAS
D. HANKE, H.-H. LANGE, and P. SAAGER *In* AGARD, Piloted Simulation Effectiveness 11 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

The Advanced Technologies Testing Aircraft System (ATTAS) is a flight test vehicle to be used as a flying simulator to demonstrate and validate new methods and technologies. In order to provide broad testing capabilities, ATTAS was heavily modified and equipped with a powerful digital fly-by-wire/light flight control system. Presented here is a technical description of the simulator structure and simulation capabilities. Also addressed is the specific role of system identification techniques for simulator validation. Several examples are given demonstrating system performance. Finally, conclusions concerning the merits of system simulation for the ATTAS development and operation are discussed. Author

N92-28549# Douglas Aircraft Co., Inc., Long Beach, CA.
THE USE AND EFFECTIVENESS OF PILOTED SIMULATION IN TRANSPORT AIRCRAFT RESEARCH AND DEVELOPMENT
J. HODGKINSON, K. F. ROSSITTO, and E. R. KENDALL *In* AGARD, Piloted Simulation Effectiveness 8 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A02/MF A03

Simulation requirements for military and for commercial transport aircraft are contrasted. The special problems introduced by active control are discussed with reference to earlier fighter data. Transport simulator experiments to explore these problems are described. Author

N92-28550# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
AN EVALUATION OF IFR APPROACH TECHNIQUES: GENERIC HELICOPTER SIMULATION COMPARED WITH ACTUAL FLIGHT
L. D. REID, S. ADVANI, and J. H. DELEEUW *In* AGARD, Piloted Simulation Effectiveness 18 p (SEE N92-28522 19-01) Feb. 1992
(Contract(s)/Grant(s): W2207-7-AF69/01-SS)
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

Described here is a comparison process using a generic helicopter simulator and flight tests carried out in the National Aeronautical Establishment's Bell 205 research helicopter. The project was designed to establish some initial application boundaries for the newly commissioned helicopter simulator. Hence, the validation process took place in the reverse order, with the helicopter simulator runs performed after the flight tests. Author

N92-28551*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPLICATION OF PILOTED SIMULATION TO HIGH-ANGLE-OF-ATTACK FLIGHT-DYNAMICS RESEARCH FOR FIGHTER AIRCRAFT
MARILYN E. OGBURN (Vigyan Research Associates, Inc., Hampton, VA.), JOHN V. FOSTER, and KEITH D. HOFFLER (Vigyan Research Associates, Inc., Hampton, VA.) *In* AGARD, Piloted Simulation Effectiveness 16 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

The use of piloted simulation at Langley Research Center as part of the NASA High-Angle-of-Attack Technology Program (HATP), which was created to provide concepts and methods for the design of advanced fighter aircraft, is reviewed. A major research activity within this program is the development of the design processes required to take advantage of the benefits of advanced control concepts for high angle of attack agility. Fundamental methodologies associated with the effective use of piloted simulation for this research are described, particularly those relating to the test techniques, validation of the test results, and design guideline/criteria development. Author

N92-28552# British Aerospace Public Ltd. Co., Lancashire (England). Military Aircraft Div.
EFFECTIVE CUEING DURING APPROACH AND TOUCHDOWN: COMPARISON WITH FLIGHT
PETER BECKETT *In* AGARD, Piloted Simulation Effectiveness 11 p (SEE N92-28522 19-01) Feb. 1992
(AGARD-CP-513) Copyright Avail: CASI HC A03/MF A03

The importance of the various cues provided by flight simulators is a topic for continual debate. Designers of simulators must wrestle with the issue in order to create a sufficient illusion of flight that allows the pilot to carry out his tasks. Hopefully, he becomes stimulated in a similar manner to the real world and behaves accordingly. For training purposes, we are then reinforcing behavior patterns. In research and development simulation, we become more confident that problems or deficiencies of pilot/aircraft interaction are identified early. Clearly, if the cueing is identical to the real world, we would expect identical behavior from the pilot. Simulators invariably fall short of this in many ways. What are considered to be essential cueing requirements are often intuitive, sometimes based on experience and sometimes completely open to individual opinion. A good test of cueing effectiveness is a comparison with flight. The cueing issues for landing approach and touchdown of fast jets are discussed here and simulation results are compared with flight. Author

N92-30769# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
TECHNICAL EVALUATION REPORT ON THE FLIGHT MECHANICS PANEL SYMPOSIUM ON PILOTED SIMULATION EFFECTIVENESS [L'EFFICACITE DE LA SIMULATION PILOTEE]
A. G. BARNES (Barnes, A. G., Lytham Saint Annes, England) Apr. 1992 17 p In FRENCH Symposium held in Brussels, Belgium, 14-17 Oct. 1991
(AGARD-AR-315; ISBN-92-835-0669-3) Copyright Avail: CASI HC A03/MF A01

This report evaluates the AGARD Flight Mechanics Panel Symposium on Piloted Simulator Effectiveness, held from 14 to 17 Oct. 1991, in Brussels, Belgium. The intention of the Symposium was to assess the benefits and the future potential of flight simulation in contributing to aircraft development, skill training, and mission training, for both fixed wing and rotary wing aircraft. In particular, contributors were asked to compare the results of simulated and real tasks. The papers were wide ranging and of high quality; several new ideas emerged. The technology of flight simulation has greatly improved since the last symposium on this topic, in 1985. The emphasis of work related to fixed wing aircraft has shifted towards systems integration. A greater contribution to helicopter design and clearance is also evident. Although new visual display devices show great promise for military flight training at high speed, low level, they are not yet fully proven, and it is recommended that an early return is made to the topic of pilot training. Simulator validation and fidelity are also of growing importance. Author

N93-10668# German Air Force, Bonn (Germany). Planning Div.
POSSIBILITIES AND LIMITATIONS OF FLYING TRAINING IN THE GERMAN AIR FORCE
H. RUEGGEBERG *In* AGARD, Combat Aircraft Noise 6 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A02/MF A03

Training is the most important task of our Air Force in peacetime, and simulation must be seen as an integral part of it. The rapid progress made in improving and advancing simulation techniques leads to a broader use of simulation in combat aircrew training. Pilots concern about reduction in flying hours in exchange for simulation missions has changed somewhat due to the fact that the total annual flying hours were reduced anyway and low level flying was restricted to 300 meters AGL without having any adequate substitute. Simulators are therefore more and more accepted as a necessary add-on for optimum combat proficiency training in which the simulator training portion will have to grow to approximately 30 to 35 percent of the future training program. The German Air Force has used simulators for all types of aircraft for many years and managed to install one special-to-aircraft type simulator in every wing. The experience gained with those systems should be investigated thoroughly to improve our knowledge of the possible application of simulators in combat training. But before we identify the principle interrelationships and longterm perspectives in a new training and simulation concept, we should collect all available data and analyze the finding from the evaluation and flight testing of the ongoing TORNADO simulator upgrade program. We should identify the shortfalls and initiate the necessary follow-on program and improve the prototype simulator before we come to any decision for the simulators in the TORNADO wings. Author

N93-13213# Aircraft Research Association Ltd., Bedford (England).
ASTOVL MODEL ENGINE SIMULATORS FOR WIND TUNNEL RESEARCH
A. E. HARRIS, G. L. WILDE (TKD Ltd., England), V. J. SMITH (TKD Ltd., England), A. R. G. MUNDELL (Defence Research Agency, Farnborough, England), and D. P. DAVIDSON (Rotadata Ltd., Derby, England) *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 10 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A02/MF A04

Feasibility studies have been conducted into the use of military turbine powered simulators (MTPS) for wind tunnel research on typical Harrier/AV8B and ASTOVL aircraft. The MTPS approach has shown significant promise for full simulation of inlet airflow ratio and nozzle thrust representations. The studies were made in two parts. In the first instance, simulation of the basic Pegasus of the Harrier/AV8B was examined. A simulator at 1 to 7.5 model scale using compressed air drive has been shown to be feasible. The design develops 467 SHP and is well adapted for use in available high-speed and low-speed wind tunnels. In the low-speed facility, a strut mounted arrangement coupled to the existing external force balance presents only minor difficulties; for the high-speed tunnel further work is required to develop/refine an internal balance/sting arrangement. Overboard bleed is used in an optimized manner to match cycle requirements to the need for minimum compressed air feed and bleed cross sectional area. In subsequent studies, cycles and layouts appropriate to the evolving ASTOVL powerplants have been examined. It is shown that MTPS designs can be developed to match a representative ASTOVL layout although compromises may be required to the support strut design to suit airfeed and bleed requirements. This paper concludes with a recommendation for a staged evolution of ASTOVL model simulations which is geared to a realistic ASTOVL project timescale in a cost effective manner. Author

N93-19706# Concordia Univ., Montreal (Quebec). Dept of Mechanical Engineering.
USE OF MICROPROCESSOR-BASED SIMULATOR TECHNOLOGY AND MEG/EEG MEASUREMENT TECHNIQUES IN PILOT EMERGENCY-MANOEUVER TRAINING
J. V. SVOBODA, RUTH M. HERON (Transportation Development Centre, Montreal, Quebec), and H. WEINBERG (Simon Fraser Univ., Burnaby, British Columbia) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 7 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

This paper shows how a combination of microprocessor-based simulator technology and magnetoencephalographic/electroencephalographic (MEG/EEG) techniques is being used in a program of research focusing on the effectiveness of training in precision flying in order to prepare general aviation pilots for emergency situations during take-off and landing. The simulator, representative of a light twin-engine aircraft, affords safe low-cost experimentation. Evoked potentials, obtained with application of MEG/EEG techniques and interpreted within the context of an information-processing model, are expected to add significantly to information obtained from conventional measures of performance and workload. The basic procedure in the series of studies in question involves exposure of experimental groups to simulator-generated formation flying scenarios, with instructions to follow the 'lead' pilot: in subsequent test scenarios requiring take-off and landing under engine failure and turbulent conditions, the performance of experimentals will be compared with that of controls. The paper concludes with a discussion of the safety implications of outcomes for general, military, and commercial aviation. Author

N93-29945# Calspan Advanced Technology Center, Buffalo, NY.

THE USAF ADVANCED TURBINE AEROTHERMAL RESEARCH RIG (ATARR)

C. W. HALDEMAN, JR., M. G. DUNN, C. D. MACARTHUR (Wright Lab., Wright-Patterson AFB, OH.), and C. G. MURAWSKI (Wright Lab., Wright-Patterson AFB, OH.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 14 p (SEE N93-29926 11-07) Feb. 1993

(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

The Advanced Turbine Aerothermal Research Rig (ATARR) has been under development and construction at Wright-Patterson Air Force Base for the past three years. Construction of the facility is now complete and demonstration experiments are underway. These demonstration experiments involve use of an instrumented turbine stage (both surface pressure and surface heat flux instrumentation) to obtain measurements for comparison with predictions, flow path measurement of total pressure, total temperature, and static pressure to determine flow path uniformity, as well as instrumentation to ascertain proper operation of all facility components. At the time of this writing, the experiments designed to obtain the data just mentioned are underway but results are not available. Therefore, the written paper will be confined to a description of: (1) the facility and its design capabilities, (2) a description of the operation of the major components with limited supporting data, e.g., main valve opening and closing times, and (3) a brief description of an uncertainty analysis that has been completed for the instrumentation and aero-performance measurements. Author

N94-10430# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany).

THE HIGH ENTHALPY FACILITIES HEG AND TH 2 IN GERMANY

G. EITELBERG and H. OLIVIER (Technische Hochschule, Aachen, Germany.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 14 p (SEE N94-10421 01-02) Apr. 1993

(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

The two high enthalpy shock tunnels in Aachen and Gottingen, Germany are described. Both of these are shock tunnels operating in the reflected mode. The Aachen tunnel has a heated driver and the Gottingen tunnel has a free piston driver. The Aachen tunnel has been in operation for a number of years already and the characteristic operating conditions of this tunnel are described. The tunnel in Gottingen (HEG) is currently being established. The first commissioning results of this tunnel are being described. The Aachen tunnel TH2 covers a testing range in air from perfect gas behavior to real gas behavior with significant oxygen dissociation effects. The HEG was designed to operate in the flow regimes where also significant nitrogen dissociation dominates. Author (revised)

N94-10431# Aeronautica Macchi S.p.A., Varese (Italy). Aerodynamics Dept.

DESIGN AND PRODUCTION OF INSULATED WIND TUNNEL MODELS OF THE HERMES SHUTTLE FOR HEAT TRANSFER MEASUREMENTS AT HYPERSONIC SPEEDS

L. VISINTINI and C. COUEDOR (Dassault Aviation, Istres, France.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 9 p (SEE N94-10421 01-02) Apr. 1993

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Among all kinds of wind tunnel experiments undertaken up to now by Dassault Aviation to develop the European HERMES shuttle, those relative to heat transfer measurements could be the last to be fully accomplished. To some extent, one could say that difficulties came from sensors themselves, from their integration conditions, and finally from additional similitude parameters not considered before. The paper introduces to Dassault Aviation so-called 'insulated models' and describes the ongoing activity developed with the collaboration of AerMacchi. The models have the purpose of making heat transfer measurements with correct simulation of surface temperatures due to its demonstrated effect on boundary layer transition. A number of pathfinder models were developed for this purpose: after a first attempt made by using a machinable ceramic, the second one was intended for surface temperatures up to 400 C and was made in a temperature resistant composite material, and the third one, able to sustain skin temperatures above 1000 C, is made by an insulating ceramic coating on a steel core. The fluid-dynamic and technological aspects related with the design and manufacture of these models are described. Author (revised)

N94-10432# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany).

THE UPGRADING OF THE ARC HEATED WIND TUNNEL OF THE DLR (LBK) WITH RESPECT TO ITS EFFECTS ON THE MATERIAL TESTING

A. GUELHAN and K. KINDLER *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 11 p (SEE N94-10421 01-02) Apr. 1993

(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

The arc heated wind tunnel (LBK) of the DLR is a useful device for high enthalpy tests of thermal protection systems of spacecrafts. The facility is described concerning its capability in simulation of the gas-surface interaction phenomena at the stagnation point of space vehicles. The working area of the tunnel resulting from tests on SiC-samples is discussed and compared with other arc heated wind tunnels. To support experimental works on the LBK numerical computations including flow solutions based on chemical equilibrium, frozen chemistry, and chemical nonequilibrium were performed. It is shown that the flow field downstream the nozzle throat is nearly frozen. Finally, the upgrading concept and the proposed performance of the facility are discussed. Author

N94-10458*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

A CFD-BASED AERODYNAMIC DESIGN PROCEDURE FOR HYPERSONIC WIND-TUNNEL NOZZLES

JOHN J. KORTE *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 10 p (SEE N94-10421 01-02) Apr. 1993

(AGARD-CP-514) Copyright Avail: CASI HC A02/MF A04

A new procedure which unifies the best of current classical design practices, computational fluid dynamics (CFD), and optimization procedures is demonstrated for designing the aerodynamic lines of hypersonic wind-tunnel nozzles. The new procedure can be used to design hypersonic wind tunnel nozzles with thick boundary layers where the classical design procedure has been shown to break down. An efficient CFD code, which solves the parabolized Navier-Stokes (PNS) equations using an explicit upwind algorithm, is coupled to a least-squares (LS) optimization procedure. A LS problem is formulated to minimize the difference between the computed flow field and the objective function, consisting of the centerline Mach number distribution and the exit Mach number and flow angle profiles. The aerodynamic lines of the nozzle are defined using a cubic spline, the slopes of which are optimized with the design procedure. The advantages of the new procedure are that it allows full use of powerful CFD codes in the design process, solves an optimization problem to determine the new contour, can be used to design new nozzles or improve sections of existing nozzles, and automatically compensates the nozzle contour for viscous effects as part of the unified design procedure. The new procedure is demonstrated by designing two Mach 15, a Mach 12, and a Mach 18 helium nozzles. The flexibility of the procedure is demonstrated by designing the two Mach 15 nozzles using different constraints, the first nozzle for a fixed length and exit diameter and the second nozzle for a fixed length and throat diameter. The computed flow field for the Mach 15 least squares parabolized Navier-Stokes (LS/PNS) designed nozzle is compared with the classically designed nozzle and demonstrates a significant improvement in the flow expansion process and uniform core region. Author (revised)

N94-34630# Naval Air Warfare Center, Warminster, PA. Flight Dynamics and Controls Branch.

APPLICATION OF CENTRIFUGE BASED DYNAMIC FLIGHT SIMULATION TO ENHANCED MANEUVERABILITY RDT/E

J. F. CALVERT and D. A. KIEFER *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 16 p (SEE N94-34605 10-05) Mar. 1994

(AGARD-CP-548) Copyright Avail: CASI HC A03/MF A03

This paper addresses the strengths of centrifuge simulation to provide the unfamiliar and severe motion environment associated with high angle of attack and post-stall maneuvering. The approach to development and testing of centrifuge motion control algorithms

is outlined, including inherent modeling constraints such as three degrees of freedom, estimated human perceptual models, and the machine-associated mechanical/structural considerations. Difficulties of algorithm development are illustrated using the results of a recent flying qualities experiment initiated to study the effects of motion on pilot ratings for proposed nose-down control power guideline criteria. Use of off-line computer models to tune algorithm performance is also presented. Finally, current capabilities of centrifuge simulation and a discussion of future applications is outlined. Author (revised)

N95-17388# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

AIRCRAFT AND SUB-SYSTEM CERTIFICATION BY PILOTED SIMULATION [HOMOLOGATION DES AERONEFS ET DE LEURS SOUS-SYSTEMES PAR LA SIMULATION PILOTEE]

Sep. 1994 53 p
(AGARD-AR-278; ISBN-92-835-0757-6) Copyright Avail: CASI HC A04/MF A01

There is a steadily increasing tendency to use piloted flight simulators for official clearance of selected areas of flight envelopes and of system behavior or malfunctions. This is a natural and desirable evolution from the wide use of simulation during the development of new aircraft. However, there is a lack of guidance for certification authorities and aircraft manufacturers on simulation standards, validation procedures and general information on the advantages and disadvantages of using simulation as part of a clearance program. This could lead to either inappropriate use of simulators, or unnecessary (and costly) reluctance to use simulation when it is appropriate. In particular, there is concern by many involved with research and engineering development simulators that subjective pilot opinion is often the primary criterion for acceptance of simulators for certification activities. However, clearance demonstrations on a simulator will not usually be experienced in flight until an operational pilot encounters the conditions or configurations of the clearance. Thus validation of the simulator for clearance tasks must involve rigorous model and simulation system validation as well as pilot subjective tests. Subjective adjustments are unacceptable. Working Group 16 was formed by the Flight Mechanics Panel of AGARD to produce an Advisory Report on this subject. The aim was to provide advice and guidance to Certification and Acceptance Authorities, and Aircraft Manufacturers on the appropriate use of piloted simulation as the sole demonstration for aircraft and system flight clearances. The Group included members from Canada, Germany, Italy, Netherlands, United Kingdom and the United States. Government R&D Establishments, Armed Service R&D Establishments, and aircraft and simulator manufacturers were all represented. Author

N95-19150# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany).

DESIGN AND OPERATION OF A THERMOACOUSTIC TEST FACILITY

G. BAYERDOERFER and L. FREYBERG *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 5 p (SEE N95-19142 05-71) Sep. 1994 Sponsored in cooperation with BMFT and the Deutsche Agentur fuer Raumfahrtangelegenheite G.m.b.H., Bonn, Germany
(AGARD-CP-549) Copyright Avail: CASI HC A01/MF A03

Aerothermal environments as encountered during the missions of reusable spacecraft, hypersonic vehicles, advanced launchers, etc. are the major design driver for an advanced Thermal Protection System (TPS) technology. In developing such materials and structures ground testing under simulated operational conditions is of eminent importance. In order to meet these requirements IABG has designed a thermoacoustic facility which was recently put into operation. The facility is able to produce surface temperatures up to 1300 C and sound pressure levels up to 160 dB. The design approach and operational aspects from test work performed so far are described. Author

N95-19267# Naples Univ. (Italy). Inst. di Aerodinamica.

ADAPTIVE WIND TUNNEL WALLS VERSUS WALL INTERFERENCE CORRECTION METHODS IN 2D FLOWS AT HIGH BLOCKAGE RATIOS

G. P. RUSSO, G. ZUPPARDI, and M. BASCIANI *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 12 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by Ministry of University and Scientific and Technological Research
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

The aim of the present work is to compare the effectiveness of adaptive-wall approach with the capabilities of WIAC (wall interference assessment and correction) methods in reducing wall interference effects in wind tunnel testing. Tests have been made in the 20 cm x 20 cm subsonic Adaptive Walls Wind Tunnel in Naples. Three different models having a chord of 100 mm, 150 mm and 200 mm have been used. The corresponding blockage ratios at alpha = 0 degrees are 6 percent, 9 percent and 12 percent, respectively. Results of the tests show that wall adaptation and measured boundary condition WIAC methods are equivalent in correcting wall interference at moderate angles of incidence and/or with medium size models (i.e. at moderate blockage ratios). Furthermore adaptive walls wind tunnels can give data correctable with a WIAC method also at very large blockage ratios as high as 4 times the blockage ratio used in conventional wind tunnels. Author

N95-19269# City Univ., London (England). Center for Aeronautics.

INTERFERENCE DETERMINATION FOR WIND TUNNELS WITH SLOTTED WALLS

M. M. FREESTONE and S. R. MOHAN *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 12 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by Dept. of Trade and Industry
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

The effectiveness of a 'two-variable' scheme, for evaluating wall interference with slotted liners installed, is assessed. Test data from transonic wind tunnel tests with a two-dimensional model geometry are utilized. In these tests untypically high levels of wall interference are produced. In the first tests, solid wall liners were used, in order to establish a standard. Selected results from two further series of tests, in which slotted roof and floor liners were fitted, are then presented and analyzed. In the first of these, divergent liners were used, and it was found that the slot flows generated large disturbances in the wall shear region, causing the normal velocity of the equivalent inviscid flow to be amplified in relation to the normal velocity in the slot. An allowance therefore had to made in the proposed interference scheme to account for this amplification. With convergent wall liners, large disturbances were avoided, and no such allowance was needed. Implications of the investigation for tests in large slotted liner wind tunnels are discussed. Author

N95-19271# McDonnell-Douglas Aerospace, Saint Louis, MO.

TRANSONIC WIND TUNNEL BOUNDARY INTERFERENCE CORRECTION

M. L. RUEGER, R. C. CRITES, R. F. WEIRICH, F. CREASMAN, R. K. AGARWAL, and J. E. DEESE *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 14 p (SEE N95-19251 05-34) Jul. 1994
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

A continuous effort in the area of transonic boundary interference correction has been underway at McDonnell Douglas Aerospace for over 6 years. A method of interference correction based on force and moment increments computed from CFD solutions was proposed in 1986. An extensive validation database has been acquired of transonic wind tunnel data for a set of geometrically similar models of different sizes. An empirical model of the flow at a porous transonic wind tunnel wall has been used in conjunction with panel codes and Euler solvers to yield corrections at a variety of conditions in both the MDA Polysonic Wind Tunnel (PSWT) and the MDA Trisonic Wind Tunnel (TWT). Author

N95-19272# British Columbia Univ., Vancouver (British Columbia). Dept. of Mechanical Engineering.
UNSTEADY FLOW TESTING IN A PASSIVE LOW-CORRECTION WIND TUNNEL
L. KONG and G. V. PARKINSON *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 7 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by Natural Sciences and Engineering Research Council
(AGARD-CP-535) Copyright Avail: CASI HC A02/MF A04

A passive low-correction wind tunnel designed for two-dimensional testing has a test section consisting of transverse airfoil-slatted side walls separating it from outer plenum chambers. The uniform spacing of the airfoil slats determines the open-area ratio (OAR). The tests described were on two sizes of NACA 0015 airfoil in plunging oscillation, and instantaneous pressure distributions were measured for different values of airfoil reduced amplitude and frequency, and over a full range of tunnel OAR. It was found that, despite the relatively large sizes of test airfoil, values of pressure, lift, and moment coefficient close to theoretical free-air values were obtained for 0.6 less than OAR less than 0.8, whereas values were much too high in the presence of solid walls and much too low in open-jet testing. Test Reynolds numbers were in the range (2.5-8.0) x 10(exp 5). Author

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ASTRONAUTICS (GENERAL)

N93-29894# Smith System Engineering Ltd., Guildford (England).
EVOLUTION OR REVOLUTION: THE CATCH 22 OF TACSATS
C. J. ELLIOTT *In* AGARD, TacSats for Surveillance Verification and C3I 7 p (SEE N93-29892 11-32) Feb. 1993 Prepared in cooperation with Smith Associates Ltd., Guildford, England
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

The potential exploitation of TACSATs is limited by a vicious circle in which users do not specify requirements which they believe to be infeasible and the space industry does not offer radically new solutions because it perceives no demand. This is the Catch 22 of the title. This paper aims to show some of the possibilities if we break out of that vicious circle. A private civilian Earth observation mission (SeaStar) is adopted as a baseline. In order to illustrate what might be possible, military payloads for surveillance, verification, and C3I are suggested, derived from land or air bases systems that either already exist or are known to be under development. It must be appreciated that these are not presented as proposed designs, merely as a kind of 'existence proof' for high performance and low cost satellites. It is possible, on the basis of this 'existence proof', to explore some of the operational consequences of the more general use of TACSATs. Author (revised)

N93-29908# Defense Advanced Research Projects Agency, Arlington, VA. Advanced Systems Technology Office.
AN OVERVIEW OF DARPA'S ADVANCED SPACE TECHNOLOGY PROGRAM
E. NICASTRI and J. DODD (Aerospace Corp., Washington, DC.) *In* AGARD, TacSats for Surveillance Verification and C3I 11 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

The Defense Advanced Research Projects Agency (DARPA) is the central research and development organization of the DoD and, as such, has the primary responsibility for the maintenance of U.S. technological superiority over potential adversaries. DARPA's programs focus on technology development and proof-of-concept demonstrations of both evolutionary and revolutionary approaches for improved strategic, conventional, rapid deployment and sea power forces, and on the scientific investigation into advanced basic technologies of the future. DARPA can move quickly to exploit new ideas and concepts by working directly with industry and universities. For four years, DARPA's Advanced Space Technology Program (ASTP) has addressed various ways to improve the performance of small satellites and launch vehicles. The advanced technologies that are being and will be developed by DARPA for small satellites can be used just as easily on large satellites. The primary objective of the ASTP is to enhance support to operational commanders by developing and applying advanced technologies that will provide cost-effective, timely, flexible, and responsive space systems. Fundamental to the ASTP effort is finding new ways to do business with the goal of quickly inserting new technologies into DoD space systems while reducing cost. In our view, these methods are prime examples of what may be termed 'technology leveraging.' The ASTP has initiated over 50 technology projects, many of which were completed and transitioned to users. The objectives are to quickly qualify these higher risk technologies for use on future programs and reduce the risk of inserting these technologies into major systems, and to provide the miniaturized systems that would enable smaller satellites to have significant - rather than limited - capability. Only a few of the advanced technologies are described, the majority of which are applicable to both large and small satellites. Derived from text

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LAUNCH VEHICLES AND SPACE VEHICLES

Includes boosters; operating problems of launch/space vehicle systems; and reusable vehicles.

N92-27902# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Wessling (Germany). Inst. for Flight Systems Dynamics.
OPTIMAL GUIDANCE ANTICIPATING MISSILE PERFORMANCE
W. GRIMM and K. H. WELL *In* AGARD, Air Vehicle Mission Control and Management 13 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

Two different guidance methods are designed for the pre-launch phase in a one-versus-one air combat situation with missiles. In both guidance schemes a missile/target simulation is performed to estimate the miss distance at the end of a fictitious missile launch. A way to do this in real time is described. The first guidance method continuously evaluates the miss distance for each aircraft against the respective opponent. The guidance is such that the ratio of the rates of the miss distances takes an optimal value from the view of the guided aircraft. Thus, it reaches a firing opportunity first. The purpose of the second guidance method is to reach a firing position against a nonmaneuvering target in minimum time. Inside the guidance algorithm, the optimal pre-launch trajectory is approximated by nonlinear programming. It serves as a reference trajectory for the guidance. In simulations the influence of different missile and target strategies in the post-launch phase is examined. The comparison with an optimal trajectory shows the near-optimal character of the guidance method. Author

N93-29903# Aerospace Corp., Los Angeles, CA.
LAUNCH VEHICLES FOR LIGHTWEIGHT TACSAT DEPLOYMENT
CHESTER L. WHITEHAIR and MALCOLM G. WOLFE *In* AGARD, TacSats for Surveillance Verification and C3I 17 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

The need for tacsats is discussed, and typical tacsat mission requirements are identified. A spectrum of potential tacsat launch systems is identified and characterized, including both U.S. and non-U.S. systems, and ranging from existing operational vehicles to very advanced vehicles that will not become available until well into the next century. The six basic launch system design drivers are presented: performance, cost, operability, launch responsiveness, launch flexibility, and survivability. These design drivers are discussed as they relate to tacsat launch requirements. The launch systems that are described are placed in the following categories: (1) mainline launch systems; (2) small fixed/relocatable/mobile launch systems; (3) ballistic missile-derived launch systems; and (4) far-term launch systems. The impact of the U.S./CIS Strategic Arms Reduction Talks

(START) agreements on the availability of surplus ballistic missiles is discussed. The availability and utility of a wide selection of global launch sites are also examined. It is concluded that the general tacsat mission is a viable concept, and possibly satisfies a very critical future need. It is demonstrated that the tacsat launch services needs into the foreseeable future can be supported by current and planned launch systems launched from existing launch sites. However, numerous other options are available and should be investigated by the tacsat system designer/planner for viability and cost effectiveness. Author (revised)

N95-20646# Westinghouse Electric Corp., Baltimore, MD.
HIGH DENSITY MONOLITHIC PACKAGING TECHNOLOGY FOR DIGITAL/MICROWAVE AVIONICS
TIMOTHY FERTIG, THERESA WALTER, ERIC GAVER, and KEVIN LEAHY *In* AGARD, Advanced Packaging Concepts for Digital Avionics 12 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

There has been a need for generic technologies and common approaches in design, development, and manufacturing of military and commercial products. This need is more pronounced and pressing today than ever before. With the objective to dramatically enhance avionics reliability, maintainability and availability (RM&A), an integrated, generic technology for packaging, cooling, and interconnection of high density and high performance circuits was developed. It is named High Density Monolithic Packaging (HDMP). Under the sponsorship of Wright Laboratory, a two-part complementary program (1990-1994), named Advanced Radio-Frequency Packaging/ARFP was contracted to Westinghouse. Under the ARFP program, the HDMP technology is being applied and its promising capability is being assessed for its ability to reduce the low power RF avionics life-cycle cost. Being better than half way through the program, the results and projections have been extremely promising. The technology assessment is approximately 50 percent complete and initial results have been extremely successful. Although the focus of the development effort has been on RF subsystems, the basic elements of HDMP technology have applications beyond RF/microwave subsystems. As digital processing speeds increase, RF/microwave design techniques must be applied to maintain high speed digital signal integrity. The basic elements of the HDMP technology are: low temperature co-fired ceramic (LTCC), solderless interconnects, multichip modules (MCM's), and composite heatsink materials. The key technology element, in this avionics availability enabling technology, is LTCC. LTCC material technology is a monolithic multilayered ceramic and conductor/metallization structure used as a substrate to support dense co-habitation of high density electronic circuits, their interconnections, and the electromechanical integrity of the integrated constituents. Author

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SPACE TRANSPORTATION

Includes passenger and cargo space transportation, e.g., shuttle operations; and space rescue techniques.

N94-10423# Avions Marcel Dassault, Saint-Cloud (France).
AERODYNAMIC AND AEROTHERMAL CHALLENGES FOR THE DESIGN OF THE HERMES SPACEPLANE
PIERRE PERRIER *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 10 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A02/MF A04

The Hermes spaceplane will represent a major step in the European space activities. It will be placed into orbit by the heavy-lift launcher Ariane 5. After completion of the mission, it will glide back from low earth orbit to its landing site. In order to take the different problems linked to the ascent and the reentry phases, an aerodynamic strategy was set up. A global review of this strategy will be made. It will contain elements on the available and necessary tools (experimental and theoretical) for the Hermes definition and qualification phases. Some aspects such as the design of the Hermes spaceplane will also be highlighted. It will review the different constraints that will be faced during the ascent and reentry phases. Constraints may come from mission requirements such as crossrange capability or from technology limits such as thermal limits on the thermal protection system or from guidance and control requirements. A new methodology was selected in order to take constraints and uncertainties into account in the design oriented towards qualification of the Hermes spaceplane. The main line of this methodology is the projection on a typical reentry trajectory of the uncertainties in the aerodynamic characteristics checked on control points. Author

N94-10459# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.
NUMERICAL METHODS FOR AEROTHERMODYNAMIC DESIGN OF HYPERSONIC SPACE TRANSPORT VEHICLES
K. M. WANIE, A. BRENNEIS, A. EBERLE, and S. HEISS *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 12 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

The requirement of the design process of hypersonic vehicles to predict flow past entire configurations with wings, fins, flaps, and propulsion system represents one of the major challenges for aerothermodynamics. In this context computational fluid dynamics has come up as a powerful tool to support the experimental work. A couple of numerical methods developed at MBB designed to fulfill the needs of the design process are described. The governing equations and fundamental details of the solution methods are shortly reviewed. Results are given for both geometrically simple test cases and realistic hypersonic configurations. Since there is still a considerable lack of experience for hypersonic flow calculations an extensive testing and verification is essential. This verification is done by comparison of results with experimental data and other numerical methods. The results presented prove that the methods used are robust, flexible, and accurate enough to fulfill the strong needs of the design process. Author (revised)

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SPACECRAFT DESIGN, TESTING AND PERFORMANCE

Includes satellites; space platforms; space stations; spacecraft systems and components such as thermal and environmental controls; and attitude controls.

N93-29893# Aerospace Corp., Los Angeles, CA.
TACTICAL SATELLITES
F. H. NEWMAN *In* AGARD, TacSats for Surveillance Verification and C3I 9 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

The concept of a Tactical Space System (TACSAT) is a means to provide a rapid, on demand, augmentation of the backbone U.S. military space systems. Such augmentation would be valuable to temporarily replace lost capability or in times of crisis, to accommodate surge demands. Because augmentation needs are not always known a-priori, it would be desirable to be able to rapidly constitute the appropriate payload-satellite bus combination to accommodate the need for a specific space capability. To do this, one can envision a standard bus capable of accepting a variety of payloads, or better yet, a single spacecraft designed to perform several different missions. Both options are considered. A number of potential missions exist in the areas of surveillance, navigation, environmental sensing, and communications. Of these, two are presented as strawman concepts: surveillance and communication. For surveillance, an electro-optical payload is described that could be used for missile surveillance, theater targeting, or weather data using the same optics, focal plane, and processor. The satellite orbit selected dictates which mission is performed. For communication, both SHF and EHF payloads are defined to provide theater coverage for the tactical user. The advantages and penalties that accrue to the use of a common bus are also explored. In addition, launch options are identified and a comparison made between 'launch-on-demand' and 'launch-on-schedule' strategies. Potential timelines for rapid launch are shown based on parallel processing and checkout of spacecraft

and launcher. This technique is compared with launching satellites on a routine basis and storing them in orbit. Energy requirements for repositioning these stored satellites after they are activated in time of need are defined. Author (revised)

N93-29896# MATRA Marconi Space, Toulouse (France). Espace/Direction des Programmes Militaires.
TACSAT-SPACECRAFT BUS CONCEPT AND DESIGN: APPLICATION OF A MULTIMISSION BUS FOR TACSAT IN LEO
GEORGES RICHARD *In* AGARD, TacSats for Surveillance Verification and C3I 13 p (SEE N93-29892 11-32) Feb. 1993 In ENGLISH and FRENCH
(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

Some details as to what is a tactical satellite, as far as such satellites are very often associated with the notion of cheap small satellites, are analyzed. The design process of a low earth orbit multimission bus for tactical application is described. Derived from text

N93-29897# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SYSTEM OF NAVIGATION BY SATELLITES WITH EUROPEAN COVERAGE [SYSTEME DE NAVIGATION PAR SATELLITES A COUVERTURE EUROPEENNE]
H. BARANGER, J. BOUCHARD, and T. MICHAL *In* AGARD, TacSats for Surveillance Verification and C3I 10 p (SEE N93-29892 11-32) Feb. 1993 In FRENCH
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

The object of this presentation is to propose a navigation system functioning according to the same principle as the GPS system but which would offer a permanent service in Europe using a limited number of satellites. The constellation presented here requires only 4 satellites including one geostationary and three satellites on geosynchronous orbits of weak inclination and eccentricity. This constellation makes it possible to completely cover Europe, the Middle-East and Africa. Moreover, the use of relatively simple satellites is possible. Indeed, all the satellites being permanently visible from the same point of the globe, it is possible to leave on the ground the ultrastable clock which provides the time reference for measurements of user-satellite distance. This constellation appears promising and a more thorough analysis is in hand in order to judge the feasibility of such a system. In particular, the problems arising from the setting and the maintenance in position of such a constellation are being analyzed right now. Several possible solutions for the installation, with single or multiple launches, from standard transfer orbits or not, are presented here. In order to provide a first evaluation of the cost of maintaining it in position, the influence of the main disturbances of orbit on the service provided was analyzed. Some examples of the maintenance in position are also provided. Transl. by FLS

N93-29898# Aerospatiale, Les Mureaux (France). Espace and Defense.
TACTICAL SATELLITES FOR AIR COMMAND AND CONTROL
M. CROCHET, J. CYMBALISTA, and L. LEVEQUE *In* AGARD, TacSats for Surveillance Verification and C3I 9 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

This paper is divided in three parts corresponding to the following items: (1) air command and control functions and deficiencies; (2) contribution of TACSATS to air command and control; and (3) operational improvements due to TACSATS. Author (revised)

N93-29904# Orbital Sciences Corp., Chantilly, VA.
SPACECRAFT AND LAUNCH SYSTEMS FOR TACSAT APPLICATIONS
CHRIS SCHADE, GILBERT D. RYE, and ROBERT H. MEURER *In* AGARD, TacSats for Surveillance Verification and C3I 11 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

The ability of a tactical communication satellite (TACSAT) space system to fulfill its mission application with the desired capability, responsiveness, reliability, and survivability, while at the same time achieving low cost objectives, is a tremendous challenge that can only be met if all of the system segments - launch, space, and ground - contribute to meeting mission unique requirements. The emerging concepts for the development, deployment, and operation of cost-effective TACSAT space systems are especially dependent on the flexibility and operability of their launch vehicle and spacecraft bus systems. Orbital Sciences Corporation (OSC) has privately developed two flexible yet cost-effective space launch vehicles--Pegasus (TM) and Taurus (TM)--with significant and unique operational capabilities that enable TACSAT space systems to meet these challenges. The Defense Advanced Research Projects Agency (DARPA) has sponsored the first launch of both systems, with follow-on launches scheduled in support of U.S. Air Force, NASA, SDIO, and commercial programs. In addition, OSC has developed a flexible, cost-effective, spacecraft bus--PegaStar (TM)--that makes common use of the Pegasus or Taurus final stage avionics and structure in an integrated systems approach, thereby optimizing the mass and volume available for payload sensors. PegaStar spacecraft for the Air Force and NASA are now in engineering and production. Author (revised)

N93-29905# Ball Corp., Boulder, CO. Space Systems Div.
QUICKSTAR: SYSTEM DESIGN, CAPABILITIES, AND TACTICAL APPLICATIONS OF A SMALL, SMART SPACE SYSTEM
THOMAS P. GARRISON and NEAL T. ANDERSON *In* AGARD, TacSats for Surveillance Verification and C3I 12 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

The QuickStar System is not a concept--it is a flight-proven design. QuickStar is a small, highly capable, low-cost, lightweight spacecraft using modern design techniques that can carry tactical assets into space at a tenth of the cost of current systems. System design, relevant technologies, payload capabilities (mass, power, data rate, pointing, volume), and tactical mission applications of this lightweight satellite are described. As part of the overall small satellite system architecture, a portable, low-cost multipurpose ground station to support production, test, launch, and orbit operations of the space segment is also available. The versatility and transportability built into the ground station allows placement at any government installation or field site. The prototype QuickStar space segment was developed to ride as a secondary payload on a McDonnell Douglas Delta 2 series expendable launch vehicle (ELV). With the extra performance provided by the Delta 2 or other ELV of similar configuration, as many as four satellites could be orbited at one time. In addition, the paper describes a QuickStar satellite configuration, incorporating the same subsystems and capabilities as the prototype QuickStar, designed for stand-alone ELV (Scout or Pegasus) launchings. The program schedule for the design, fabrication, and test of a QuickStar satellite system reflects the fast-paced environment of a low-cost program. Minimal paper and much concurrent engineering goes into a schedule that provides a flight-ready spacecraft and supporting ground station in only 15 months. Author (revised)

N93-29906# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Space Communications and Propulsion Systems Div.
ATTITUDE- AND ORBIT CONTROL SUBSYSTEM CONCEPTS FOR TACSATS
H. BITTNER, E. BRUEDERLE, M. SURAUER, and M. SCHWENDE *In* AGARD, TacSats for Surveillance Verification and C3I 24 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

An attempt has been made to identify the configuration, the equipment, and the necessary technology of an Attitude- and Orbit Control Subsystem (AOCS), which can provide the necessary flexibility for serving the large variety of TACSAT mission objectives and the associated performance requirements. This discussion is based on more than 20 years of experience in AOCS design and development for communication and application spacecraft (S/C). Author (revised)

N93-29911# Hughes Aircraft Co., Los Angeles, CA. Remote Sensing Systems.
LOW COST TACSAT FOR NATO SURVEILLANCE
CHARLES S. HOFF *In* AGARD, TacSats for Surveillance Verification and C3I 8 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

Cost and performance technology breakthroughs in recent years have made possible the near term development and deployment of a low cost TACSAT surveillance system. The potential for both

the spacecraft and sensor to be launched on lower cost launch systems is the fundamental basis for reduced system cost. Additionally, the spacecraft and sensor must be amenable to low cost mass production. For all weather, day/night surveillance, an active synthetic aperture radar (SAR) is the ideal instrument, and the ability to mass manufacture thousands of very low cost transmit/receive (T/R) modules was developed at Hughes. Since the size of a SAR increases as the orbital altitude is increased, a final element of the economical basis for a low cost TACSAT is the definition of low earth orbit (LEO) space constellations with high mission utility. Tradeoffs are also provided to compare sparse or zero based peacetime constellations with surge launch capabilities to small peacetime early warning space constellations that can also instantly provide regional combat support on demand. Author

N93-29912# Lockheed Missiles and Space Co., Sunnyvale, CA.
COST EFFECTIVE TACSATS FOR MILITARY SUPPORT
M. T. BRODSKY, M. D. BENZ, and J. T. NEER *In* AGARD, TacSats for Surveillance Verification and C3I 12 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

The key space system features required to provide effective support to military field units are discussed and Lockheed's concept to fill critical niches in military surveillance and remote sensing is discussed. The military is aware of benefits available from more effective use of space. To provide those benefits, space systems must be dependable, easy to use, flexible, responsive, and affordable. How a programmable, multi-spectral E-O sensor combined with a new small satellite bus and supporting command and control and data processing tools can provide environmental and surveillance support to users in peacetime, crisis, and combat is discussed. Also discussed are how such a system meets essential military utility criteria and an approach for rapid TacSat system development, evaluation, and deployment. Author (revised)

N94-10428# Fluid Gravity Engineering Ltd., Witley (England).
PLANETARY ENTRY VEHICLE DESIGN FOR PLANNED AND POTENTIAL ESA MISSIONS TO TITAN, MARS, AND EARTH RETURN (FGE TN 51/92)
ARTHUR SMITH *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 12 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

Design of ballistic planetary entry probes for planned ESA/NASA Titan, Mars, and Earth-Return missions is discussed with emphasis on the common design constraints. The choice of aeroshell configuration and some of the simple design rules are outlined which are used initially at pre-feasibility stages. These include the influence of body dynamics, conventional aerodynamics, and aerothermodynamics. Prediction of the aerothermodynamic environment and influence of uncertainties in the basic physics and chemistry are seen to dominate. Analysis methodology and some of the ESA sponsored experimental program which was initiated to tackle the lack of basic chemistry data is discussed. Author (revised)

N94-11319# Phillips Lab., Edwards AFB, CA.
ADAPTIVE STRUCTURES FOR SPACECRAFT: A USAF PERSPECTIVE
ALOK DAS, GLENN ORMBREK (Wright Lab., Wright-Patterson AFB, OH.), and MICHAEL OBAL (Strategic Defense Initiative Organization, Washington, DC.) *In* AGARD, Smart Structures for Aircraft and Spacecraft 13 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

The precise pointing/shape control needs of future space systems coupled with a 10-20 year life requirement and very stringent limitation on system weight has motivated a new approach in control system design. This approach, referred to as 'adaptive structures,' exploits recent breakthroughs in advanced composite materials, sensors and actuators, and intelligent control concepts to provide an integrated structure/controller. Author (revised)

N94-11320*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DYNAMIC TESTS ON THE NASA LANGLEY CSI EVOLUTIONARY MODEL
H. TROIDL (Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn, Germany.) and K. B. ELLIOTT *In* AGARD, Smart Structures for Aircraft and Spacecraft 9 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A02/MF A04

A modal analysis study, representing one of the anticipated 'Cooperative Spacecraft Structural Dynamics Experiments on the NASA Langley CSI Evolutionary Model', was carried out as a sub-task under the NASA/DLR collaboration in dynamics and control of large space systems. The CSI evolutionary testbed (CEM) is designed for the development of Controls-Structures Interaction (CSI) technology to improve space science platform pointing. For orbiting space structures like large flexible trusses, new identification challenges arise due to their specific dynamic characteristics (low frequencies and high modal density) on the one hand, and the limited possibilities of exciting such structures and measuring their responses on orbit on the other. The main objective was to investigate the modal identification potential of several different types of forcing functions that could possibly be realized with on-board excitation equipment using a minimum number of exciter locations as well as response locations. These locations were defined in an analytical test prediction process used to study the implications of measuring and analyzing the responses thus produced. It turned out that broadband excitation is needed for a general modal survey, but if only certain modes are of particular interest, combinations of exponentially decaying sine functions provide favorable excitation conditions as they allow to concentrate the available energy on the modes being of special interest. From a practical point-of-view structural nonlinearities as well as noisy measurements make the analysis more difficult, especially in the low frequency range and when the modes are closely spaced. Author (revised)

N94-11323# Strategic Defense Initiative Organization, Washington, DC.
THE SATELLITE ATTACK WARNING AND ASSESSMENT FLIGHT EXPERIMENT (SAWAFE)
MICHAEL OBAL, BILL SAYLOR, HUGH S. MURRAY, MARTIN R. SWEET, DAN HOLDEN, and CALVIN MOSS *In* AGARD, Smart Structures for Aircraft and Spacecraft 13 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

A program to develop an advanced satellite health and status monitoring subsystem for detecting and discriminating hostile threats is described. The threats considered are laser, radio frequency, and x-rays. The subsystem uses lightweight electronics and sensors that are imbedded in the satellite structure to minimize the integration impact on the host satellite. The sensor materials are described. The first of a series of flight experiments is also described. Author

N94-11342# Rome Univ. (Italy). Dipt. Aerospaziale.
ON POSSIBLE APPLICATIONS OF SMART STRUCTURES TO CONTROL OF SPACE SYSTEMS
F. BETTI, P. GASBARRI, P. GAUDENZI, F. PERSIANI (Bologna Univ., Italy.), G. M. SAGGIANI (Istituto Studi e Applicazioni Scienze Aeronautiche Spaziali, Forli, Italy.), and P. SANTINI *In* AGARD, Smart Structures for Aircraft and Spacecraft 14 p (SEE N94-11317 01-24) Apr. 1993 Sponsored in part by Ist. Studi e Applicazioni Scienze Aeronautiche Spaziali
(Contract(s)/Grant(s): 293/62)
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

The general equations for a multi-body space system with internal control forces are written. Single body, or 'local', equations of motion are written and then they are transformed into global equations, associated with a sufficient number of 'internal' equations describing the relative motions of the various parts of the system. In such a transformation, quantities of two orders of magnitude arise: the first group is associated with the Earth's equatorial radius, and the second group is associated with a characteristic length of the spacecraft. The two groups are separated in order to avoid round-off errors. Furthermore, a law of control associated with deformations of the connections between the elements of the system is introduced, in such a way that

efficient control of instability phenomena may be possible. Numerical examples complete the work. Author

N94-28020# Laboratoire d'Aerothermique du CNRS, Meudon (France).

CONTROL JETS IN INTERACTION WITH HYPERSONIC RAREFIED FLOW [JETS TRANSVERSAUX EN INTERACTION AVEC DES ECOULEMENTS HYPERSONIQUES RAREFIES]

J. ALLEGRE and M. RAFFIN *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 9 p (SEE N94-28003 07-34) Nov. 1993 In FRENCH Sponsored by ESA

(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

Control jets are used on space vehicles in order to replace or complement mechanical aerodynamic controls at high altitudes. As a matter of fact, the efficiency of mechanical controls decreases drastically with higher rarefaction levels of external flow. Control jets were experimentally investigated in wind-tunnels. The jets interact with external hypersonic rarefied flows. Jet efficiency and associated interaction mechanisms were analyzed for two types of configurations. The first configuration is a delta wing with transverse control jets issuing from sonic nozzles located close to the trailing edge. Tests are performed with an external hypersonic air flow characterized by a Mach number of about 8, a Reynolds number of 11,000, and a rarefaction parameter V = 0.077. The second configuration is a corner flow interacting with a transverse jet issuing from one hypersonic nozzle. This nozzle is inserted in one of the two walls which make up the corner model. Tests are made under external hypersonic nitrogen flows characterized by a Mach number of about 20 and dynamic pressures ranging from 20 Pa to 620 Pa covering rarefaction levels associated with reentry conditions. Author (revised)

N94-29324# National Aerospace Lab., Amsterdam (Netherlands).

THE DEVELOPMENT PROCEDURES AND TOOLS APPLIED FOR THE ATTITUDE CONTROL SOFTWARE OF THE ITALIAN SATELLITE SAX

G. J. HAMEETMAN and G. J. DEKKER *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 8 p (SEE N94-29315 08-61) Nov. 1993

(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The Italian satellite (with a large Dutch contribution) SAX is a scientific satellite which has the mission to study roentgen sources. One main requirement for the Attitude and Orbit Control Subsystem (AOCS) is to achieve and maintain a stable pointing accuracy with a limit cycle of less than 90 arcsec during pointings of maximal 28 hours. The main SAX instrument, the Narrow Field Instrument, is highly sensitive to (indirect) radiation coming from the Sun. This sensitivity leads to another main requirement that under no circumstances the safe attitude domain may be left. The paper describes the application software in relation with the overall SAX AOCS subsystem, the CASE tools that have been used during the development, some advantages and disadvantages of the use of these tools, the measures taken to meet the more or less conflicting requirements of reliability and flexibility, and the lessons learned during development. The quality of the approach to the development has proven the (separately executed) hardware/software integration tests. During these tests, a neglectible number of software errors has been detected in the application software. Derived from text

N94-30350# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.

TACSATS FOR NATO [LES SATELLITES TACTIQUES POUR L'OTAN]

Feb. 1994 70 p

(AD-A277710; AGARD-AR-322; ISBN-92-835-0733-9) Copyright Avail: CASI HC A04/MF A01

Tactical satellites (TacSats) are studied to determine their utility in meeting the needs of theater commanders. Six mission areas are studied: battlefield surveillance, communications, tactical missile warning and assessment, regional maritime surveillance, navigation, and weather. The synergistic role between strategic and tactical satellites is also considered. TacSat system concepts are provided in most mission areas as are means of implementing TacSat systems, including the launch and ground system segments. Issues raised in these areas are discussed. Finally, TacSat costs are discussed and the Working Group's conclusions and recommendations are provided. Author (revised)

N94-36616# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

POINTING AND TRACKING SYSTEMS [SYSTEMES D'ACQUISITION ET DE POURSUITE AUTOMATIQUES]

May 1994 188 p In ENGLISH and FRENCH The 57th symposium was held in Seattle, WA, 12-15 Oct. 1993

(AD-A282573; AGARD-CP-539; ISBN-92-835-0741-X) Copyright Avail: CASI HC A09/MF A02

This volume contains the 19 unclassified papers, presented at the Guidance and Control Panel Symposium held in Seattle, the United States from the 12th to the 15th of October, 1993. The papers presented cover the following areas: (1) overview of pointing and tracking systems and techniques; (2) optical pointing and tracking systems; (3) weapon control and mechanical systems; (4) pointing and tracking algorithms; and (5) sensor fusion. For individual titles, see N94-36617 through N94-36634.

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SPACECRAFT INSTRUMENTATION

N93-29909# Alenia Spazio S.p.A., Rome (Italy).

SAR SENSORS ON TACSATS: A FEASIBILITY ASSESSMENT

G. PERROTTA *In* AGARD, TacSats for Surveillance Verification and C3I 9 p (SEE N93-29892 11-32) Feb. 1993

(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

The feasibility of installing SAR's on board lightsats for tactical and strategic observation missions is discussed, emphasizing high resolution and short revisit intervals as main system drivers. Lightsat constellations design criteria are presented for both global and limited latitude belt coverage. Pros and cons of sunsynchronous versus medium inclination non-sunsynchronous orbits are discussed. Gross system trade offs for the SAR sensor are then addressed, in the specific context of a resource-limited lightsat, stressing the achievement of resolutions better than 5 m, swaths greater than 20 Km, access angles of at least 30 deg, small antenna dimensions, and a reasonable power consumption. Both X and C band SAR solutions are outlined. Data transmission alternatives are also discussed, in the context of tactical and strategic scenarios, outlining their projected performance. Constellation orbits control and platform attitude are also addressed for their impact on mission, SAR image quality and satellite design requirements. Key aspects of critical platform subsystems are also identified. Author (revised)

N93-29910# MATRA Marconi Space Portsmouth, Hampshire (England).

A TACSAT SAR CONCEPT

C. D. HALL, C. J. BAKER (Defence Research Agency, Malvern, England.), G. E. KEYTE (Defence Research Agency, Farnborough, England.), and L. M. MURPHY (Defence Research Agency, Farnborough, England.) *In* AGARD, TacSats for Surveillance Verification and C3I 14 p (SEE N93-29892 11-32) Feb. 1993

(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

The payload concept covered is that of a low cost, high performance radar sensor capable of detecting and recognizing static objects within an imaged scene of the Earth's surface using the Synthetic Aperture Radar (SAR) technique. The overall system is integrated with a TACSAT platform in Low Earth Orbit (LEO) and, although only passing reference is made to this feature, the radar could also have a capability for the detection of Ground Moving Targets (GMTI). A parametric review of such a sensor in the light of the target and background features to be observed is provided. A design concept is included showing the possible hardware realization of a candidate system, as well as budgets for the mass, size, power, and pointing requirements of the instrument. Additional design features considered are the influence that short duration missions may have on hardware redundancy and the effect of short, low duty-cycle observation periods on

solar array and battery sizing. The way towards a low cost R and D demonstrator system allowing a practical investigation of the key techniques and technologies is addressed. Author (revised)

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SPACECRAFT PROPULSION AND POWER

Includes main propulsion systems and components, e.g., rocket engines; and spacecraft auxiliary power sources.

N92-33245# Hercules, Inc., Rocket Center, WV. Ballistics Lab.
HAZARDS REDUCTION FOR TACTICAL MISSILES
K. O. HARTMAN *In* AGARD, Insensitive Munitions 22 p (SEE N92-33240 23-28) Jul. 1992
(AGARD-CP-511) Copyright Avail: CASI HC A03/MF A03

Substantial progress has been made over the past four years in characterizing and understanding the response of energetic materials and rocket motors to the energetic stimuli specified in MIL-STD-2105A. Approaches to reducing the sensitivity based upon that work are reviewed. Minimum smoke propellants with an improved performance shock sensitivity balance were formulated. Partial or complete replacement of the nitramine with phase stabilized ammonium nitrate reduced the shock sensitivity significantly at a performance loss of 4 to 10 percent. A number of routes to more extinguishable composite propellants, both reduced smoke and high performance types, are discussed. Replacement of the polybutadiene with alternative polymeric backbones has yielded more extinguishable compositions. The use of metal perchlorates in place of the ammonium perchlorate greatly increases thermal stability. In the area of inert components, alternatives to monolithic metal cases, such as composite cases, substantially improve the response to fast cook-off and, for minimum smoke propellants, to bullet impact. Author

N93-17607# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
AIRBREATHING PROPULSION FOR MISSILES AND PROJECTILES [PROPULSION AEROBIE DES MISSILES ET PROJECTILES]
Sep. 1992 217 p In ENGLISH and FRENCH Presented at the Propulsion and Energetics Panel 79th Symposium, Villepreux, France, 11-15 May 1992
(AGARD-CP-526; ISBN-92-835-0685-5; AD-A257018) Copyright Avail: CASI HC A10/MF A03

The Conference Proceedings contains 15 papers and a Keynote Address presented at the Propulsion and Energetics Panel 79th Symposium on 'Airbreathing Propulsion for Missiles and Projectiles' which was held 11-15 May 1992 in Villepreux, France. The Symposium was arranged in the following sessions: Ramjets and Ramrockets: Survey papers; Ramjets and Ram Rockets: Propulsion Systems; Ramjets and Ram Rockets: Combustion, Fuels, Materials; Projectile Airbreathing Propulsion; Aerodynamics and Engine Integration; Turbojets and Turborockets; and Common Techniques. The Technical Evaluation Report is included at the beginning of the Proceedings. Questions and answers of the discussions follow some of the papers. Nineteen additional classified papers will be published in a classified volume. The Symposium was intended to be a forum for discussing advances made in this field since the conduct of a similar Symposium in the autumn of 1981. For individual titles, see N93-17608 through N93-17622.

N93-17608# Aerospatiale, Chatillon (France).
RAMJET PROPULSION FOR MISSILES IN THE MACH 3 TO 4.5 RANGE [PROPULSION PAR STATOREACTEUR POUR MISSILES DANS LE DOMAINE MACH 3 A 4,5]
JEAN-MARIE LAURENT and PASCAL GARNERO *In* AGARD, Airbreathing Propulsion for Missiles and Projectiles 9 p (SEE N93-17607 05-20) Sep. 1992 In FRENCH
(AGARD-CP-526) Copyright Avail: CASI HC A02/MF A03

New requirements that call for increases in range and improved penetration ability have forced the newest generation of missiles to fly higher and faster. Ramjet propulsion lends itself well to these requirements. However, the most recent technical specifications are very demanding when compared to those that were required of the first generation of missiles. The following topics are presented: air intakes; fuels; thermal protection of the combustion chamber; and forecasting and testing facilities. The technologies necessary for the production of missiles capable of speeds in the Mach 3-4.5 range exist, but the costs of these technologies must be reduced in order to facilitate the development of such missiles. Transl. by FLS

N93-17609# Defence Research Agency, Farnborough, Hampshire (England). Air Vehicle Performance Dept.
POTENTIAL MISSILE FLIGHT PERFORMANCE GAINS FROM IMPROVEMENTS TO THE PROPULSION SYSTEM
M. S. IVEY and R. K. OLDHAM *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 14 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

Future developments in the propulsion of ramjet powered missiles will aim to widen the launch envelope, extend the operating range, and lengthen the period of powered flight to give a more potent terminal maneuver phase. In this paper, some of the possible methods of achieving these aims were critically assessed for typical stand-off and air-to-air missiles. For both types of missile, the use of a high density fuel for the main propellant would produce quite significant performance gains. However, storage and plume visibility problems have to be overcome. Gains can also be made for both missiles by optimizing the relative amounts of boost and main propellant to match the required launch envelope. The benefits of inlet and exhaust variability were explored for the stand-off missile. The latter option is the more favorable prospect for range enhancement, but the design of a low pressure loss variable mechanism will be difficult. The range of the air-to-air missile depends primarily on its launch Mach number and the range can be further increased by using a highly lofted trajectory with an unpowered terminal phase. The maximum and minimum fuel flow rates needed for this missile are related to the altitude limits of its flight envelope. Author

N93-17610# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).
DEVELOPMENT TESTING OF THROTTLEABLE DUCTED ROCKETS
HANS-LUDWIG BESSER *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 13 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

Throttleability, being a current requirement for modern air-breathing missile propulsion systems, adds considerable complexity to the development of ducted rockets. Problems are especially inherent in the development of the following: (1) pressure sensitive propellants; (2) hot gas valves (especially for particle laden flow); and (3) ramcombustors featuring high performance over widely varying operating conditions. The use of propellant ingredients with high heating value but unfavorable combustion characteristics, like boron, is an additional challenge in the development of high energy ducted rocket systems. Extensive testing and a well conceived test philosophy are needed to achieve satisfactory development results. MBB, together with its subsidiary Bayem-Chemie, has been engaged in the field of throttleable ducted rockets for more than a decade. This paper summarizes test procedures which were established to address the strongly interrelated development problems and presents examples of test results derived from the development of a ducted rocket engine for a supersonic antiship missile. Author

N93-17611# Johns Hopkins Univ., Laurel, MD. Applied Physics Lab.
THE DUAL COMBUSTOR RAMJET: A VERSATILE PROPULSION SYSTEM FOR HYPERSONIC TACTICAL MISSILE APPLICATIONS
PAUL J. WALTRUP *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 11 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

Procedures for designing and maximizing the performance of Dual Combustor Ramjet (DCR) engines and vehicles powered by this engine are presented. Comparisons of DCR powered vehicles with scramjet powered vehicles for Mach 4 to 8 flight show that the DCR provides better performance at the Mach 4 flight condition, while the scramjet is better at Mach 8. Comparisons of the DCR

with a ramjet for Mach 3 to 6 flight, with both having the same, but low, thrust level at Mach 3, show that the DCR exhibits better performance at and near the cruise condition at Mach 6 and similar performance during acceleration. Suggested additional comparisons to broaden the scope of the conclusions are also given. Author

N93-17619# Naval Air Warfare Center, Trenton, NJ. Aircraft Div.
DEVELOPMENT AND QUALIFICATION OF THE US CRUISE MISSILE PROPULSION SYSTEM
WILLIAM H. REARDON and ANTHONY J. CIFONE *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 15 p (SEE N93-17607 05-20) Sep. 1992
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03
This paper provides a description of the very successful Cruise Missile gas turbine propulsion program managed by the United States Department of Defense. The paper contains a summary of the procurement process, the technical and programmatic milestones, issues and challenges, and lessons learned. In the past fifteen years, testing at the Naval Air Propulsion Center has included over 800 cruise engine development and component substantiation efforts spanning the engine specification qualification requirements. This paper provides a detailed account of environmental test techniques used to qualify the F107 family of gas turbine engines which propel the U.S. Cruise Missile. In addition, a missile freestream flight test simulation for the TOMAHAWK Cruise Missile is discussed along with current and future program efforts. Author

N93-22998# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
TERMINOLOGY AND ASSESSMENT METHODS OF SOLID PROPELLANT ROCKET EXHAUST SIGNATURES [METHODES D'EVALUATION DES SIGNATURES DES PROPULSEURS A PROPERGOL SOLIDE]
Feb. 1993 271 p
(AGARD-AR-287; ISBN-92-835-0699-5) Copyright Avail: CASI HC A12/MF A03
The Propulsion and Energetics Panel's Specialists' Meeting in autumn 1985 on Smokeless Propellants demonstrated that no common standard was available in this field and that the lack of common understanding led to misunderstanding amongst the NATO community. After some preparatory discussion, the Panel, therefore, formed Working Group Number 21 with the objectives of defining methods for the assessment of rocket motor exhaust optical properties in the visible and in the infrared range, and of recommending a terminology based on quantitative criteria. The Working Group discussed the subject in a total of eight sessions and prepared this Advisory Report. Following an Introduction and Summary there are six chapters, commencing with an Overview and continuing with Propellant Smoke Classification, Plume Primary Smoke, Plume Secondary Smoke, Plume Radiation and Plume Microwave Properties. In most cases, the conclusions and recommendations follow the chapters and are not repeated at the end of the report. Author (revised)

N93-29907# Alenia Spazio S.p.A., Rome (Italy).
ELECTRIC PROPULSION FOR LIGHTSATS: A REVIEW OF APPLICATIONS AND ADVANTAGES
G. PERROTTA, GIANFRANCO F. CIRRI (Proel Tecnologie, Florence, Italy.), and GIOVANNI MATTICARI (Proel Tecnologie, Florence, Italy.) *In* AGARD, TacSats for Surveillance Verification and C3I 7 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03
The paper reviews the advantages and limitations of electric propulsion for lightsats characterized by a launch mass in the 300 to 800 kg range. The considered systems include ion propulsion, arc jets, and stationary plasma thrusters for different applications such as drag compensation, orbit raising, fine trimming of orbital parameters, and various orbit transfers. Electric propulsion provides substantial mass savings and turns out to be an enabling technology for certain lightsat missions. The constraints resulting from DC power limitations on board small satellites are discussed, along with the implications on candidate technologies and system solutions. A review of near term prospectives of low power ion thrusters, for lightsats applications, concludes the paper.
Author (revised)

N94-15217# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
ROCKET MOTOR PLUME TECHNOLOGY [L'ETUDE DES JETS DES MOTEURS-FUSEES]
Jun. 1993 196 p In ENGLISH and FRENCH Lecture series held in Neubiberg, Germany, 7-8 Jun. 1993 and in Ankara, Turkey, 10-11 Jun. 1993
(AGARD-LS-188; ISBN-92-835-0713-4; AD-A268719) Copyright Avail: CASI HC A09/MF A03
Requirements for missile guidance and stealth properties are changing and becoming more stringent. There is no up-to-date synthesis relating rocket motor plume properties to these new requirements. The work performed and recently finished within PEP WG 21 formed the basis for this Lecture Series. The scope of the Lecture Series will be rocket motor exhaust products and plumes in all their aspects. Plume properties are addressed and methods of numerical simulation and experimental assessment described. Specifically, plume structure, after-burning phenomena, primary and secondary smoke, plume radiation signatures, and plume microwave interactions are described in detail. Operational aspects linked to these topics discuss how rocket plumes influence missile detection, guidance, and tracking. Ways in which plumes may be modified to reduce or eliminate this influence are suggested. For individual titles, see N94-15218 through N94-15223.

N94-15218# Societe Nationale des Poudres et Explosifs, Vert-Le-Petit (France).
PLUME PRIMARY SMOKE
J. C. CHASTENET *In* AGARD, Rocket Motor Plume Technology 19 p (SEE N94-15217 03-20) Jun. 1993
(AGARD-LS-188) Copyright Avail: CASI HC A03/MF A03
The exhaust from a solid propellant rocket motor usually contains condensed species. These particles, also called 'Primary Smoke', are often prejudicial to missile detectability and to the guidance system. To avoid operational problems it is necessary to know and quantify the effects of particles on all aspects of missile deployment. A brief description of the origin of the primary smoke is given. It continues with details of the interaction between particles and light as function of both particles and light properties (nature, size, wavelength, etc). The effects of particles on plume visibility, attenuation of an optical beam propagated through the plume and the contribution of particles on optical signatures of the plume are also described. Finally, various methods used in NATO countries to quantify the primary smoke effects are discussed. Author (revised)

N94-15219# Royal Ordnance PLC, Kidderminster (England). Rocket Motors Div.
PROPULSION
P. K. SMITH *In* AGARD, Rocket Motor Plume Technology 24 p (SEE N94-15217 03-20) Jun. 1993
(AGARD-LS-188) Copyright Avail: CASI HC A03/MF A03
Current requirements for missile systems increasingly stress the need for stealth capability. For the majority of missile systems and missions, the exhaust plume is likely to be the major contributor to overall missile signature, especially considering the recent developments in low emission and low Radar Cross Section coatings for motor bodies. This implies the need for the lowest possible rocket exhaust signature over a wide range of frequencies from the UV through visible and IR to microwave and radio frequencies. The choice of propellant type, Double Base; Composite etc, plays a significant part in determining the exhaust signature of the rocket motor as does the selection of inert materials for liners, inhibitors, and nozzles. It is also possible with certain propellants to incorporate additives which reduce exhaust signature either by modifying the chemistry or the afterburning plume or more significantly by suppressing secondary combustion and hence dramatically reducing plume temperature. The feasibility of plume signature control on the various missions envisaged by the missile designer is considered. The choice of propellant type and hardware components to give low signature is discussed together with performance implications. Signature reduction results obtained over a wide range of frequencies are also presented. Author (revised)

N94-15220# Phillips Lab., Edwards AFB, CA. Propulsion Directorate.
SECONDARY SMOKE
P. A. KESSEL *In* AGARD, Rocket Motor Plume Technology 10 p (SEE N94-15217 03-20) Jun. 1993
(AGARD-LS-188) Copyright Avail: CASI HC A02/MF A03

The open literature on secondary smoke formation, prediction, and classification is briefly reviewed. This review was limited to the open literature in order to promote the widest possible discussion within the AGARD engineering community. The recently completed PEP WG 21 proposal for smoke classification is presented. Secondary smoke is defined and the physics of condensation of vapor onto droplets is reviewed. The basis for the existing droplet condensation models is discussed and the existing methodology for predicting secondary smoke light attenuation and scattering is presented. Test data taken to establish the initial conditions for heterogeneous nucleation in rocket plumes is presented. Comparisons between secondary smoke predictions and flight data are presented. The state of the art of secondary smoke modeling is discussed and suggestions are made for improvements. Author

N94-15221# Science Applications International Corp., Fort Washington, PA. Propulsive Sciences Div.
ROCKET MOTOR PLUME FLOWFIELDS: PHENOMENOLOGY AND SIMULATION
SANFORD M. DASH *In* AGARD, Rocket Motor Plume Technology 30 p (SEE N94-15217 03-20) Jun. 1993
(AGARD-LS-188) Copyright Avail: CASI HC A03/MF A03

The varied processes occurring in rocket motor exhaust plumes and methodology for simulating these processes are described. Rocket motor plumes contain shock waves due to under/overexpansion; the exhaust mixes with the external stream in a highly compressible turbulent environment; unburnt products of combustion after-burn strongly at lower altitudes; and solid propellant plumes contain particulates which are generally out of equilibrium with the gas-phase exhaust. Earlier methodology simulated the varied processes using boundary layer type coupling. Current methods implement solutions of the full or reduced (parabolized) Navier-Stokes equations where all fluid dynamic and thermochemical processes are strongly coupled. Earlier methodology are reviewed briefly while the status of current methods is addressed in greater detail. Author (revised)

N94-28032# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany). Inst. for Experimental Fluid Mechanics.
FIRST EXPERIMENTAL ASSESSMENT OF RCS PLUME-FLOW FIELD INTERACTION ON HERMES LEADING EDGE THRUSTER CONFIGURATION
T. POERTNER *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 13 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A03/MF A04

Glow discharge flow visualization experiments are demonstrated which have been performed to enable a first assessment of the HERMES 1.0 leading edge thruster configuration concerning interference between the thruster plumes of the reaction control system (RCS) and the surrounding flow field. The results of the flow visualization tests are presented in exemplary selected photographs. Additional Pitot pressure measurements support assumptions concerning interference induced pressure changes that may result from the observed significant flow field disturbances. Author

N95-17278# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
EXPERIMENTAL AND ANALYTICAL METHODS FOR THE DETERMINATION OF CONNECTED-PIPE RAMJET AND DUCTED ROCKET INTERNAL PERFORMANCE [METHODES EXPERIMENTALES ET ANALYTIQUES POUR LA DETERMINATION EN CONDUITE FORCEE DES PERFORMANCES DES STATOREACTEURS ET DES STATOFUSEES]
Jul. 1994 103 p
(AGARD-AR-323; ISBN-92-835-0755-X) Copyright Avail: CASI HC A06/MF A02

Connected-pipe, subsonic combustion ramjet and ducted rocket performance determination procedures used by the NATO countries have been reviewed and evaluated. A working document has been produced which provides recommended methods for reporting test results and delineates the parameters that are required to be measured. Explanations and detailed numerical examples are presented covering the determination of both theoretical and experimental performances, the use of air heaters and uncertainty and error analysis. Author

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COMPOSITE MATERIALS

Includes physical, chemical, and mechanical properties of laminates and other composite materials.

N92-33033# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
THE UTILIZATION OF ADVANCED COMPOSITES IN MILITARY AIRCRAFT [L'EMPLOI DES MATERIAUX COMPOSITES DE POINTE POUR LES AVIONS MILITAIRES]
Apr. 1992 194 p In ENGLISH and FRENCH The 73rd meeting was held in San Diego, CA, 7-11 Oct. 1991
(AGARD-R-785; ISBN-92-835-0666-9; AD-A253004) Copyright Avail: CASI HC A09/MF A03

The purpose of this workshop was to identify the current state of the art in key issues related to compression loading and fluid effects in composite materials. In the area of compression loading, there was considerable concern over the different results obtained from various test methods. It was agreed that failure modes produced by the various test methods along with a better fundamental understanding of compression failure were key issues in the development of compression test methods. In the area of fluid effects, a lack of a comprehensive data base hampers identification of key mechanisms leading to fluid degradation. This is further complicated by the fact that interactions depend on the fluid and composite under consideration. For individual titles, see N92-33034 through N92-33054.

N92-33034# Dayton Univ., OH.
ISSUES IN COMPRESSION LOADING OF COMPOSITE STRUCTURES
JAMES M. WHITNEY *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 5 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A01/MF A03

Compression loading causes difficulty in development of test methods and failure criteria. Compression testing has produced considerable controversy with a number of different experimental methods being considered. Each method, however, often produces different values of apparent compression strength. The failure mode is the key issue, as each test may produce a different failure mode. In addition, the failure modes often depend on fiber and matrix properties and on laminate geometry. When data is reported, the failure mode is often ignored. In analyzing failure modes, one must consider how relevant the test geometry and load introduction is to the actual application for which the data is being generated. Development of failure criteria also creates difficulty because of the various possible failure modes. Author

N92-33035# Dayton Univ. Research Inst., OH.
A NEW TEST METHOD TO DETERMINE THE COMPRESSIVE STRENGTH OF FIBER-REINFORCED COMPOSITES
A. S. CRASTO, R. Y. KIM, and J. M. WHITNEY (Wright Lab., Wright-Patterson AFB, OH.) *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 12 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A03/MF A03

The measured compression strength of advanced composites is sensitive to specimen inhomogeneities, loading geometry, and test conditions. Consequently, the reported strength is not an intrinsic material property, but simply the failure stress under compression loading, and varies widely for a given composite system. To obtain a more accurate measure of the material property, premature failure must be avoided, and a specimen was specifically designed for this purpose. The specimen is a miniature sandwich beam with identical composite skins on either side of a neat resin core, and can be tested in axial compression as well as four-point flexure. The axial compressive properties of epoxy composites reinforced with carbon, glass, and boron filaments, and composites of carbon fibers in a polyetheretherketone (PEEK) matrix has been evaluated with this specimen in an IITRI test fixture. Failure occurred predominantly in the gage section for unidirectional composites at composite stresses and strains substantially higher than those observed with all-composite test coupons and with substantially less variation in the data. Multidirectional laminates also displayed higher strengths with the sandwich specimen. Author

N92-33036# British Aerospace Aircraft Group, Warton (England). Materials and Development Dept.
ASPECTS OF COMPRESSION IN AEROSPACE COMPOSITES: FUTURE REQUIREMENTS
STUART GREEN *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 13 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A03/MF A03

To keep the overall mass of combat aircraft to a minimum level, and to optimize performance, designers have exploited the benefits offered by advanced polymer composite materials. The ability to resist load in compression is, however, particularly important in some aircraft structures such as wings. Advantages in terms of reduced mass and increased performance to be gained with composite materials is highlighted in this paper. A general overview is given of the materials science aspects of compression and compression after impact. Recent developments aimed at improving the reliability of compression test data is reviewed. Author

N92-33037# Nottingham Univ. (England). Dept. of Theoretical Mechanics.
THREE-DIMENSIONAL ELASTICITY ANALYSIS OF BUCKLING OF LAMINATED PLATES
A. J. M. SPENCER *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 5 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A01/MF A03

The analysis of failure mechanisms for laminated composite materials depends on obtaining a three dimensional analysis of the elastic stress and deformation in the material, with particular regard to interlaminar stresses. A transfer matrix method is used which determines the stress and displacement at any point in the plate in terms of the stress and displacement at a reference surface. Standard two dimensional equations governing these surfaces may be solved by numerical methods. Elastic buckling of plates subject to pre-stress is investigated in this paper. Buckling is treated as a bifurcation from the initial stress state, giving rise to an eigenvalue problem. Author

N92-33038# Royal Aerospace Establishment, Farnborough (England). Materials and Structures Dept.
A REVIEW OF RAE SPONSORED WORK ON THE COMPRESSIVE BEHAVIOUR OF COMPOSITE MATERIALS
P. T. CURTIS *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 9 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

The Non-metallic Materials Division at RAE has mounted a major program to study the compressive behavior of composite materials and seek improvements in compressive strength. This is being done by developing improved compressive test techniques, studying failure processes fractographically, investigating the effect of notches and impact damage, and modelling these behaviors mathematically to develop a predictive capability. Author

N92-33039# Institute for Aerospace Research, Ottawa (Ontario).
INFLUENCE OF EDGE EFFECT ON COMPRESSION-TENSION FATIGUE OF TOUGHENED GRAPHITE/EPOXY LAMINATES
J. P. KOMOROWSKI, J. B. R. HEATH, D. LEFEBVRE (Sherbrooke Univ., Quebec), C. ROY (Sherbrooke Univ., Quebec), and R. MASMOUDI (Sherbrooke Univ., Quebec) *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 7 p (SEE N92-33033 23-24) Apr. 1992
(Contract(s)/Grant(s): FE220788NRC21)
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

Results are reported of fatigue tests on a toughened graphite/epoxy (IM6/5245C) using a specimen and grip design that allows a relatively large volume of material to be tested. The loading was compression dominated with specimens having a layup of (0/45/90)-(44.4 percent,44.4 percent,11.1 percent). Specimen stiffness and residual strength were measured. Results indicate that fatigue in composite specimens is dominated by the edge effects. The proper selection of stacking sequence is crucial in achieving long fatigue lives. Under compression dominated loading, fatigue is a local process, with damage always initiating at the edge and could be related to interlaminar shear stresses. The fatigue process consists of a relatively long period before initiation, followed by a period of rapid growth leading to compressive failure. Author

N92-33040# Institute for Aerospace Research, Ottawa (Ontario).
DAMAGE PROGRESSION UNDER COMPRESSIVE LOADING IN COMPOSITE LAMINATES CONTAINING AN OPEN HOLE
C. POON, N. C. BELLINGER, R. W. GOULD, and M. D. RAIZENNE *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 16 p (SEE N92-33033 23-24) Apr. 1992
(Contract(s)/Grant(s): FE220788NRC21)
(AGARD-R-785) Copyright Avail: CASI HC A03/MF A03

An experimental investigation into damage progression in compressively loaded quasi-isotropic laminates with a circular hole and the prediction of damage initiation using 3-D finite element failure analysis is described. Notched laminated plates were fabricated from Narmco IM6/5245C with three different stacking sequences. The tests revealed that the notched strength decreased as the ply group thickness increased. Based on the numerical and experimental results, a mechanism for damage initiation and progression was proposed. However, considering the damage initiation occurred at 90 percent of the ultimate load, a damage progression model would not be practical for the material systems presently used in aircraft. Author

N92-33041# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PROPAGATION OF A DELAMINATION IN A COMPOSITE PANEL SUBJECTED TO A COMPRESSION LOAD [PROPAGATION D'UN DELAMINAGE DANS UN PANNEAU COMPOSITE SOUMIS A UN CHARGEMENT DE COMPRESSION]
R. GIRARD *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 9 p (SEE N92-33033 23-24) Apr. 1992 In FRENCH Previously announced in IAA as A92-16123
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

The DAM-STRAT finite element code is used to study the propagation of an artificial delamination between two layers of a laminate plate subjected to compression forces. The propagation is preceded by local buckling and a rupture of the layers along two sides of the rectangular delamination zone. The problem is analyzed in the framework of large displacements in the buckling and postbuckling regions. The results obtained demonstrate that DAM-STRAT is an effective tool for predicting various phenomena associated with the compression of composite panels with an initial delamination. Author

N92-33042# National Aerospace Lab., Amsterdam (Netherlands).
GARTEUR COMPRESSION BEHAVIOUR OF ADVANCED CFRP
W. G. J. THART, R. AOKI (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Stuttgart, Germany, F.R.), H. BOOKHOLT (Fokker B.V., Amsterdam, Netherlands), P. T. CURTIS (Royal Aerospace Establishment, Farnborough, England), I. KROEBER (Deutsche Airbus G.m.b.H., Bremen, Germany, F.R.), N. MARKS (Westland Helicopters Ltd., Yeovil, England), and P. SIGETY (Office National d'Etudes et de Recherches Aerospatiales, Paris, France) *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 6 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

The susceptibility of currently used carbon fiber reinforced plastics (CFRP) to impact damage has stimulated the development of improved composites. This new generation of composites shows increased toughness and damage tolerance as well as improved tensile performance. This is generally not matched by an improvement in compressive properties which then become the limiting factor. To improve the compressive strength, a better understanding of the compressive failure modes is needed. For experimental verification of failure models, special attention must be paid to compressive test procedures in order to achieve optimal strength values with minimum scatter. Author

N92-33043# Dassault-Breguet Aviation, Saint-Cloud (France).
INNOVATIVE CONSTITUENTS REQUIREMENTS TO IMPROVE COMPOSITES COMPRESSIVE STRENGTH
L. ANQUEZ and P. VAUTEY *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 10 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

While the recent development of intermediate modulus carbon fibers led to very high specific tensile strength over the first generation of high strength composites, the composite compressive properties did not improve at all. Because most aeronautical structures are subject to alternate tension and compression, it is not possible to take full advantage of carbon fiber composites, as the compressive loading becomes the design limitation. After a focus on the matrix dominating role in composite compression behavior, this paper will clear out which matrix characteristics, stiffness or strength, determines the unidirectional compressive failure. H.A.

N92-33044# Alenia, Foggia (Italy). Engineering Dept. for Advanced Composite Structures.
CFRP STIFFENED PANELS UNDER COMPRESSION
A. BUCCI and U. MERCURIO *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 14 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A03/MF A03

The purpose was to experimentally demonstrate the validity of the conceptual carbon fiber reinforced plastics (CFRP) stiffened panel suitable for application in the unpressurized aft fuselage of a middle size aircraft. Both theoretical and experimental behavior have been analyzed taking into account the effects of different materials, curvature, impact damage, and static and fatigue loads. Composite materials with stiff fibers of the last generation coupled with toughened thermosetting resin systems were used. Author

N92-33045# British Aerospace Aircraft Group, Warton (England). Materials and Development Dept.
AN OVERVIEW OF CONCERNS RELATING TO FLUID EFFECTS ON COMPOSITES
GEOFFREY A. WRIGHT *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 6 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

The effect of the interaction of fluids on composite fiber/resin systems plays an important role in determining the suitability and design values used for these materials. A brief overview is provided of the questions posed by the designer and the materials engineer and looks at the test methodologies proposed to answer these questions. The advantages for standardization of these fluid/environment exposure regimes, together with agreement on the range and extent of the follow-up tests is examined. Author

N92-33046# Construcciones Aeronauticas S.A., Madrid (Spain). Research and Development, Technology and Materials Dept.
EFFECTS OF FUEL ON HERCULES AS-4/8552 COMPOSITE MATERIAL
A. T. RODRIGUEZ, A. LAVIA, I. FERNANDEZ, and E. REDONDO *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 6 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

The behavior of an advanced toughened epoxy resin/carbon fiber composite material, Hercules AS-4/8552, in contact with fuel has been studied. Interlaminar shear strength and compression strength tests were performed on unidirectional specimens after being exposed at 70 C to several conditions, including a combined exposure of JP8 and water. A correlation between the fluid content and the drop of the mechanical properties was found. The exposure to fuel or additive mixtures of impacted samples was found not to produce any effect in the damage size or detectability. Fuel leakage tests were conducted on impacted panels subjected to pressure and results are presented. Finally, the growth of micro-organisms in fuel/water solutions seemed not to effect the material properties, as deduced from some mechanical and microscopy studies carried out on samples exposed to such mixtures. Author

N92-33047# Naval Air Development Center, Warminster, PA.
ENVIRONMENTAL DEGRADATION OF HIGH TEMPERATURE COMPOSITES
R. C. COCHRAN, T. M. DONNELLAN, R. E. TRABOCCO, and J. THOMPSON (Naval Air Systems Command, Washington, DC.) *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 12 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A03/MF A03

A study was performed to assess the effect of galvanic corrosion phenomena on the strength of graphite/bismaleimide (BMI) composites. The results indicate that degradation occurred in BMI composites galvanically coupled to aluminum alloys. The mechanism responsible for the degradation involves hydroxyl ion generation in the cathodic reaction. Optical and electron microscopy of the surface of coupled specimens showed a great deal of cracking and degradation of the resin. This phenomena is thought to be associated with stresses in the resin imposed by thermal or chemical processes. These cracks may be an indication that the mechanism of degradation is not simply the hydroxyl attack on the resin but a combination of chemical and mechanical attack. Composite-aluminum material couples were exposed to salt water/fuel solutions and to salt spray environments after which material properties were determined. Conventional protection schemes were evaluated. The results indicate that the performance retention was test specific and that the bearing tests were most sensitive to the galvanic reaction. In addition, a systematic study of the electrochemical conditions which were most important in control of the degradation rates was performed. Author

N92-33048# Centre d'Essais Aeronautique Toulouse (France).
EVALUATION OF THE EFFECTS OF THE ENVIRONMENT ON THE BEHAVIOR OF THE PRIMARY STRUCTURES OF COMPOSITE MATERIAL AIRCRAFT IN SERVICE: HISTORIC AND CURRENT SITUATION [PRISE EN COMPTE DES EFFETS DE L'ENVIRONNEMENT SUR LE COMPORTEMENT EN SERVICE DES STRUCTURES PRIMAIRES D'AVIONS EN MATERIAU COMPOSITE: HISTORIQUE ET SITUATION ACTUELLE]
JEAN ROUCHON *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 7 p (SEE N92-33033 23-24) Apr. 1992 In FRENCH
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

When the first application of composite materials with an organic base in the working structures of aircraft were envisaged, the greatest preoccupation of the designers and service officials was their behavior while aging. Some fifteen years later, the experience acquired in service associated with the numerous results obtained from the laboratory has greatly dissipated those fears, at least for structures not calling for extensive usage of composite technology. This does not mean that the aging of composites does not occur, but rather that the consequences are now considered to have limited and predictable impact. In other words, they are susceptible to being accounted for at the level of conception, certification, and thereafter in use in the structures. The principal steps leading to the current situation are retraced, and then analyzed to account

for the phenomena of aging, in particular the determination of the concentration of water absorbed by the composite during use. Transl.

N92-33049# Wright Lab., Wright-Patterson AFB, OH.
FLUID EFFECTS: THERMOSET AND THERMOPLASTIC MATRIX COMPOSITES
D. B. CURLISS *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 8 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

The sensitivity of several advanced composites to military jet fuel, JP-4, was investigated. The materials were processed into laminates using the manufacturer's recommended process. The test specimens were immersed in JP-4 in a sealed pressure vessel at 180 F. After 1680 hours of exposure, the mechanical properties of the composites along with any weight gain were examined. Material property degradation and other physical effects from exposure to jet fuel are presented in this study. Author

N92-33050# Patras Univ. (Greece). Dept. of Mechanical Engineering.
JET FUEL ABSORPTION AND DYNAMIC MECHANICAL ANALYSIS OF CARBON FIBRE COMPOSITES
S. A. PAIPETIS and V. KOSTOPOULOS *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 6 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

Fluid absorption of carbon fiber composites, both thermosetting and thermoplastic, immersed in jet fuel under controlled conditions of time and temperature, was determined and, in the sequence, DMA studies were performed. Storage modulus, loss factor, and glass transition temperature were the parameters utilized for the evaluation of the dynamic behavior of these materials. Author

N92-33051# Institute for Aerospace Research, Ottawa (Ontario). Structures and Materials Lab.
FRACTURE SURFACE CHARACTERISTICS OF COMPRESSIVE FAILURES IN CARBON FIBRE REINFORCED EPOXY LAMINATE SUBJECTED TO HOT/WET CONDITIONING
S. LEE, P. C. GAUDERT, and R. F. SCOTT *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 8 p (SEE N92-33033 23-24) Apr. 1992 Sponsored by Dept. of National Defence and National Research Council of Canada
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

Results of an investigation are presented into the effects of environmental exposure on the compressive fracture surface characteristics of carbon/epoxy composite materials such as Hercules AS-4/3501-6. The effects of temperature and absorbed moisture on laminates are explored. Specimens were preconditioned in either ambient laboratory humidity or in water at 64 C for four to seven weeks. The fractures were produced at room temperature and 93 C. The observed fracture features, by scanning electron microscope, of the specimens with different preconditioning and test environments are presented. These results illustrated differences in the amount of fiber/matrix separation, fiber fracture, and resin fracture with increasing temperature and absorbed moisture. The reduction in compressive strength of laminates due to hygrothermal effects is also discussed. Author

N92-33052# Middle East Technical Univ., Ankara (Turkey).
THE EFFECT OF HEAT TREATMENT ON THE PROPERTIES OF PEEK AND APC-2
A. ANKARA, G. KALAY, and M. J. FOLKES (Brunel Univ., Uxbridge, England) *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 7 p (SEE N92-33033 23-24) Apr. 1992 Sponsored in part by NATO
(AGARD-R-785) Copyright Avail: CASI HC A02/MF A03

This paper examines the effects of certain heat treatments on the properties of PEEK and carbon fiber reinforced PEEK. Tests were performed to study the changes in the amount of crystallinity and observe the effect this crystallinity change had on the other properties. DSC thermograms showed that there is no considerable change in crystallinity melting point of the composite specimens dependent on the heat treatment applied. Higher glass transition temperatures were observed for specimens with a higher crystallinity percentage. The frequency effect on the dynamic mechanical spectrum was also determined, and showed that this quantity is decreased to lower temperatures and the loss tangent increases in value. Flexture testing showed that the flexture properties are independent of crystallinity. Author

N92-33053# Alenia, Foggia (Italy).
ENVIRONMENTAL RESISTANCE OF AMORPHOUS BONDED THERMOPLASTIC JOINTS
C. VOTO and M. IANNONE *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 5 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A01/MF A03

Amorphous bonding appears to be a promising method of joining thermoplastic matrix advanced composites. The temperature to bond, lower than for fusion bonding, and the limited dimension of the melted zone, allow significant cost reduction and guarantee good mechanical characteristics. On the other hand, a potential problem exists, due to lower resistance to aeronautical solvents and service fluids, because of the amorphous nature of the bonding layers. The basic resistance to environmental degradation of the resins used for bonding, and the chemical stability of their blends with the semicrystalline matrices of the adherends, have been investigated. Author

N92-33054*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLIGHT SERVICE ENVIRONMENTAL EFFECTS ON COMPOSITE MATERIALS AND STRUCTURES
H. BENSON DEXTER and DONALD J. BAKER (Army Aviation Research and Technology Activity, Hampton, VA.) *In* AGARD, The Utilization of Advanced Composites in Military Aircraft 13 p (SEE N92-33033 23-24) Apr. 1992
(AGARD-R-785) Copyright Avail: CASI HC A03/MF A03

NASA Langley and the U.S. Army have jointly sponsored programs to assess the effects of realistic flight environments and ground-based exposure on advanced composite materials and structures. Composite secondary structural components were initially installed on commercial transport aircraft in 1973; secondary and primary structural components were installed on commercial helicopters in 1979; and primary structural components were installed on commercial aircraft in the mid-to-late 1980's. Service performance, maintenance characteristics, and residual strength of numerous components are reported. In addition to data on flight components, 10 year ground exposure test results on material coupons are reported. Comparison between ground and flight environmental effects for several composite material systems are also presented. Test results indicate excellent in-service performance with the composite components during the 15 year period. Good correlation between ground-based material performance and operational structural performance has been achieved. Author

N93-21507# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
DEBONDING/DELAMINATION OF COMPOSITES [LE DECOLLEMENT ET LE DELAMINAGE DES MATERIAUX COMPOSITES]
Dec. 1992 289 p Presented at the 74th Meeting of the AGARD Structures and Materials Panel, Patras, Greece, 24-29 May 1992 Original contains color illustrations
(AGARD-CP-530; ISBN-92-835-0696-0; AD-A263503) Copyright Avail: CASI HC A13/MF A03

Composite laminate components are prone to debonding/delamination when subjected to high interlaminar stress or when under impact. While delamination failure in itself is not usually catastrophic, its influence on a component may lead to subsequent failure modes. Hence debonding or delamination may reduce the strength of an aircraft or its fatigue life. The objective of the Specialists' Meeting, organized in the Spring of 1992, was to review the present state-of-the-art in the analysis, detection, and repair of delamination. Twenty-nine excellent papers were presented to an audience of over 100 leading specialists from NATO countries. Discussion of the papers presented and the final summary session revealed some common concerns and issues and gave rise to several recommendations. In bringing together the various experiences of air forces, governments, industries, and universities, the meeting has helped to identify the key issues. For individual titles, see N93-21508 through N93-21534.

N93-21508# Wright Lab., Wright-Patterson AFB, OH.
FREE EDGE DELAMINATION PREVENTION IN COMPOSITE LAMINATES
N. J. PAGANO and S. R. SONI (Adtech Systems Research, Inc., Dayton, OH.) *In* AGARD, Debonding/Delamination of Composites 11 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A03/MF A03

The key to success in the prevention of free edge delamination is the understanding of stress components and contributing factors responsible for the onset of delamination. The contributing factors may be fiber/matrix properties, ply orientations, and stacking sequence. In the past two decades the authors have done extensive theoretical and experimental investigations on this topic. As a result of their continuous work in this area a unique software package, 'Automated System for Composite Analysis' was developed. The effectiveness of the Automated System for Composite Analysis (ASCA) for identifying the contributions of the influencing factors responsible for the onset of delamination and help select safer configurations. For this purpose two material systems (one polymer matrix composite AS4/3501 and one metal matrix composite SCS6/Ti) were considered. These two composites represent highly orthotropic and near quasi-isotropic material properties. Author

N93-21509# Army Aerostructures Directorate, Hampton, VA.
DELAMINATION AND FATIGUE OF COMPOSITE MATERIALS: A REVIEW
T. K. OBRIEN and W. ELBER *In* AGARD, Debonding/Delamination of Composites 11 p (SEE N93-21507 07-24) Dec. 1992
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Research exploring the role of delamination on the durability and damage tolerance of advanced composite materials is reviewed. Recent studies on the characterization of composite delamination are summarized. Recent analytical solutions for interlaminar stresses and strain energy release rates associated with common sources of delamination are also reviewed. The role of delamination in (1) low velocity impact, (2) residual compression strength, and (3) fatigue is highlighted. Delamination is shown to be the common damage mode observed in all of these problems. A Damage Threshold/Fail-safety concept for addressing composite damage tolerance is discussed. Author

N93-21510# Wright Lab., Wright-Patterson AFB, OH. Structures Div.
INITIATION AND PREVENTION OF EDGE DELAMINATION WITH AND WITHOUT RESIDUAL STRESSES
R. S. SANDHU, G. P. SENDECKYJ, G. A. SCHOEPPNER, and J. E. PAPPAS *In* AGARD, Debonding/Delamination of Composites 20 p (SEE N93-21507 07-24) Dec. 1992
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The total delamination moment (DM) is shown to be a quantitative criterion for predicting delamination initiation in composite laminates near free edges. To determine the initiation of delamination near free edges, DM of the laminate is compared to the critical delamination moment obtained experimentally. Specially designed specimens incorporating variable radius geometries are used to determine the critical DM. The analytical technique coupled with the experimental data is used to minimize the tendency of the laminates to delaminate without increasing the designed thickness of the laminates. In addition, residual curing stresses are included in the analytical technique to determine their effect on the initiation of edge delamination. Author

N93-21511# Brussels Univ. (Belgium). Composite Systems and Adhesion Research Group.
NUMERICAL ANALYSIS OF THE THERMOELASTIC EFFECTS IN LAMINATED STRUCTURES AND ITS USE IN THE IDENTIFICATION OF DEFECTS
D. VANHEMELRIJCK, L. SCHILLEMANS, P. DEWILDE, A. CARDON, M. KYRIAKOPOULOS (Patras Univ., Greece.), and G. ROUPAKIAS (Patras Univ., Greece.) *In* AGARD, Debonding/Delamination of Composites 6 p (SEE N93-21507 07-24) Dec. 1992 Sponsored in part by Belgian National Foundation for Scientific Research
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The thermoelastic effect first analyzed by Lord Kelvin is governed by a simple relation between amplitude of temperature and amplitude of sum of principle stress change as long as adiabatic conditions are maintained. Although valid for isotropic materials it is shown that this simple relation leads to very poor results for anisotropic materials. A non-adiabatic theory taken into account the inter-laminar heat transfer shows a better agreement between theory and experiment. Experimental data were obtained on a Fibredux 914C-TS-5-34 percent carbon epoxy laminate using single point measurements. Author

N93-21512# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.
PREDICTING FAILURE BY DEBONDING/DELAMINATION
G. A. O. DAVIES and P. ROBINSON *In* AGARD, Debonding/Delamination of Composites 28 p (SEE N93-21507 07-24) Dec. 1992 Sponsored by Commission of the European Communities and Defence Research Agency
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The need for predicting delamination or debonding in carbon fiber composite structures in two situations where the effect is crucial is highlighted. First, interior barely visible damage due to low velocity impact is discussed, and second, the debonded joint between panel and stiffener in a post-buckled compression panel is addressed. It is shown that for impact damage a stress-based failure criteria might work for thin plates less than 2mm thick but as the thickness increases a fracture model becomes necessary. A strategy for bridging this gap and also avoiding the need for a hypothetical flaw is advocated. An improved method for finding mode 3 fracture toughness is shown. Author (revised)

N93-21513# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. for Structural Mechanics.
GARTEUR DAMAGE MECHANICS FOR COMPOSITE MATERIALS: ANALYTICAL/EXPERIMENTAL RESEARCH ON DELAMINATIONS
M. GAEDKE, D. J. ALLMAN (Royal Aircraft Establishment, Farnborough, England.), C. CZEKAJSKI (Aerospatiale, Toulouse, France.), H. EGGERS, D. GILETTA (Office National d'Etudes et de Recherches Aerospatiales, Paris, France.), R. GIRARD (Office National d'Etudes et de Recherches Aerospatiales, Paris, France.), R. HILLGERT (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany.), J. LAMERIS (National Aerospace Lab., Amsterdam, Netherlands.), R. F. MOSLEY (Aerospatiale, Toulouse, France.), and R. T. POTTER (Aerospatiale, Toulouse, France.) *In* AGARD, Debonding/Delamination of Composites 11 p (SEE N93-21507 07-24) Dec. 1992
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Currently used carbon fiber reinforced plastics (CFRP) - mainly with epoxy matrices - show a sensitive reaction to impact damage which stimulated the establishment of a cooperation program within GARTEUR (Group of Responsibles for Structures and Materials). Studies in this field had shown that delamination is a critical damage in this area for airframe structures with principal points of concern of tendency of buckling of delaminated areas and potential growth of delaminations. Author (revised)

N93-21514# Aerospatiale, Paris (France). Joint Research Center.
BUCKLING AND POST-BUCKLING BEHAVIOR OF A DELAMINATION IN A CARBON-EPOXY LAMINATED STRUCTURE: EXPERIMENTS AND MODELLING
D. GUEDRA-DEGEORGES, S. MAISON, D. TRALLERO, and J. L. PETITNIOT (Institut de Mecanique des Fluides de Lille, France.) *In* AGARD, Debonding/Delamination of Composites 11 p (SEE N93-21507 07-24) Dec. 1992 Sponsored by Ministry of Defence
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Results for the following studies are presented: (1) experimental identification of sensitivity to local buckling and characterization of post buckling behavior of a delamination in a plate under compression; and (2) performing nonlinear three dimensional finite element computations in order to establish local buckling loads, shape of the blister, load levels, and direction related to the propagation of the delamination. Author (revised)

N93-21515*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PROGRESSIVE DELAMINATION IN POLYMER MATRIX COMPOSITE LAMINATES: A NEW APPROACH
C. C. CHAMIS, P. L. N. MURTHY, and L. MINNETYAN (Clarkson Univ., Potsdam, NY.) *In* AGARD, Debonding/Delamination of Composites 9 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03

A new approach independent of stress intensity factors and fracture toughness parameters has been developed and is described for the computational simulation of progressive delamination in polymer matrix composite laminates. The damage stages are quantified based on physics via composite mechanics while the degradation of the laminate behavior is quantified via the finite element method. The approach accounts for all types of composite behavior, laminate configuration, load conditions, and delamination processes starting from damage initiation, to unstable propagation, and to laminate fracture. Results of laminate fracture in composite beams, panels, plates, and shells are presented to demonstrate the effectiveness and versatility of this new approach. Author

N93-21516# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
DELAMINATION DAMAGE AND ITS EFFECT ON BUCKLING OF LAMINATED CYLINDRICAL SHELLS
R. C. TENNYSON and S. KRISHNA KUMAR *In* AGARD, Debonding/Delamination of Composites 6 p (SEE N93-21507 07-24) Dec. 1992
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The task of the project engine designer is to determine what type, size and arrangement of propulsion system is best suited to any particular aircraft requirement. This task involves a compromise between many aspects, notably between engine or installation, performance and weight, and also, nowadays, cost as well. This compromise has to be achieved within the known or projected state of the art in thermodynamic and aerodynamic design, mechanical and structural design, and the way in which these design arts react upon each other. Most studies in engine design commence with a parametric study of the main thermodynamic variables, i.e., pressure ratio, turbine entry temperature (TET) and by-pass ratio, and their effect on specific fuel consumption (sfc) and specific thrust. This study will be based upon a given level of component efficiency which will reflect the aerodynamic state of knowledge which is considered appropriate to the estimated service date of the engine or propulsion system. Derived from text

N93-21517# Alenia Aeronautica, Turin (Italy). Materials Technology Dept.
FRACTURE ANALYSIS OF BMI SYSTEM IN PRESENCE OF MOISTURE
G. BARBISO and M. R. BOCCUTI *In* AGARD, Debonding/Delamination of Composites 9 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03

Working with today's composite materials not predicted phenomena mainly related to the matrix chemical behavior can occur. Delaminations on solid laminate and honeycomb structure using a bismaleimide (BMI) resin have been detected. Analysis of the delaminated parts have been carried out to understand the nature of the defect. Correlation of the chemical behavior affecting the mechanical properties and the solution to overcome the delamination problems are described. Author

N93-21518# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
MODELISATION AND COMPUTATION OF COMPOSITE MATERIALS
GEORGES DUVAUT *In* AGARD, Debonding/Delamination of Composites 5 p (SEE N93-21507 07-24) Dec. 1992 Prepared in cooperation with Paris VI Univ., France
(AGARD-CP-530) Copyright Avail: CASI HC A01/MF A03

Composite materials are more and more widely used in aeronautical and spacial engineering and industry. Their main advantage is the gain in weight but it is not the only one: noncorrosion and their ability to assume complex functions without bearings are also very valuable in some cases. The drawback is the difficulty to predict their behavior and write valuable constitutive relations to perform structure computations. This is due to the microscopic heterogeneities and the various phases and interfaces whose behavior is not well-known. In this paper, we propose a homogenization method which allows, when the microscopic structure can be assumed periodic at some intermediate scale, to build a constitutive relation from the assumed knowledge of the behavior of the various phases and interfaces. Author

N93-21519# Institute for Aerospace Research, Ottawa (Ontario).
EDGE DELAMINATION OF COMPOSITE LAMINATES
C. POON, N. C. BELLINGER, Y. XIONG, and R. W. GOULD *In* AGARD, Debonding/Delamination of Composites 13 p (SEE N93-21507 07-24) Dec. 1992 Sponsored by De Havilland Aircraft Co. of Canada Ltd.
(AGARD-CP-530) Copyright Avail: CASI HC A03/MF A03

A review of the literature and the research performed at the Institute for Aerospace Research on the subject of delamination in composite laminates are presented. Delamination is known to initiate at free edges where the influence of interlaminar stresses is significant. These interlaminar stresses are three dimensional and cannot be calculated by the laminated plate theory. State-of-the-art stress analysis methods for interlaminar stresses are reviewed with emphasis on the reliability of finite element methods. The strength of materials and fracture mechanics approaches for the prediction of delamination onset and growth are discussed. Results of edge delamination, double cantilever beam, and end notch flexure tests for toughened resin composites are presented. The effects of delamination on structural integrity are investigated by conducting cyclic tests on bread board specimens representing the bolted joint interface between the ply build-up ends of the composite arm booms and the metallic flanges of a sophisticated robotic system for space application. The onset of delamination at the curved edge of an open hole under compressive loading is detected using acoustic emission techniques and penetrant-enhanced x-radiography. The effects of impact-induced delaminations on the residual compressive strength of composite laminates are predicted using a model based on sublaminate buckling. Preliminary verification of the model shows good agreement between experimental and predicted results. Author

N93-21520# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany). Inst. fuer Strukturmechanik.
SYNERGISM BETWEEN LAYER CRACKING AND DELAMINATIONS IN MD-LAMINATES OF CFRE
H. EGGERS, H. C. GOETTING, and H. BAEUML *In* AGARD, Debonding/Delamination of Composites 9 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03

The synergism between successive layer cracking and delamination growth was studied for laminates fabricated out of T300/914C solely. Unidirectional (UD) and fiber dominated multidirectional (MD) laminates were tested after static or fatigue loading. Typical examples for damage mechanisms were analyzed numerically and used to develop damage conditions. An increase of the damage resistance was observed for MD-laminates stacked by quasi-unidirectional (plus or minus 2)-double layers (QD-layers). In crossply laminates of various stacking sequences, the crack distances were measured on the inner 90 degree-layers after T-fatigue loading. Expressions for the mean crack distances and the residual layer stiffness were developed in dependence of layer thicknesses, mean layer strain epsilon perpendicular to the fibers and number of load cycles. For the Characteristic Damage State (CDS) an energy condition was established to evaluate the crack distances A(sub CDS) for brittle matrices. In order to describe more properly the delamination growth interferred by layer cracking, a second order tensor was established for the released energy. The mean values of this tensor are the common energy release rates (ERR) for the different crack modes and the first invariant is the total ERR. But the ERR-tensor has three invariants, which can be used to establish more complex damage conditions. Author

N93-21521# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany). Inst. for Structures and Design.

DELAMINATION DEVELOPMENT UNDER FATIGUE LOADING

R. M. AOKI and J. HEYDUCK *In* AGARD, Debonding/Delamination of Composites 7 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03

Examples of delamination development in carbon-fiber reinforced plastic (CFRP) impact damaged specimens and structural parts under tensile and compressive fatigue loading investigated with the help of the ultrasonic in-situ (USIS) method are presented. The evaluation of the ultrasonic rear echo shows the manifold ways of delamination development depending on materials used, configuration of specimens, as well as loading conditions. Author

N93-21523# Royal Aerospace Establishment, Farnborough (England).

MODE 2 DAMAGE DEVELOPMENT IN CARBON FIBRE REINFORCED PLASTICS

M. J. HILEY and P. T. CURTIS *In* AGARD, Debonding/Delamination of Composites 11 p (SEE N93-21507 07-24) Dec. 1992 Sponsored by Ministry of Defence
(AGARD-CP-530) Copyright Avail: CASI HC A03/MF A03

A study of the mode 2 interlaminar fracture toughness of unidirectional carbon fiber reinforced plastics has been made using the End Notched Flexure (ENF) test. A range of fiber reinforced thermosetting prepreg systems including a bismaleimide and four epoxy materials have been investigated, plus the thermoplastic PEEK. A comparison between the materials showed the thermoplastic to be significantly tougher than any of the thermosetting systems. The two phase epoxy system 914 and the BMI V390 had the lowest toughness, with values of only 20 percent of those of the APC2 PEEK. The potential link between mode 2 fracture toughness and delamination growth and impact damage tolerance has been assessed. Measurements of delamination growth in mode 2 fatigue, for three of the materials, have also been made. Potential links with the materials susceptibility to the growth of delaminations and more generally impact damage during fatigue loading have also been considered. Author

N93-21524# Wright Lab., Wright-Patterson AFB, OH. Flight Dynamics Directorate.

BARELY VISIBLE DAMAGE THRESHOLD IN A BMI

EDVINS DEMUTS and RAGHBIR S. SANDHU *In* AGARD, Debonding/Delamination of Composites 6 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03

This paper presents the test plan, equipment and procedures employed and results obtained in an experimental investigation of IM7/5260 graphite bismaleimide's resistance to low velocity impact. The two velocities used were approximately 15 ft/sec for the four groups of thicker and approximately 10 ft/sec for the group of the thinnest specimens. The planform dimensions of the specimens were 7 in. x 10 in. The effect of two different layups 10/80/10 and 40/50/10 (percent of 0 degree/plus or minus 45 degree/90 degree plies) on impact resistance was investigated. There were five thicknesses for the 10/80/10 layup - 9, 26, 48, 74, 96 plies and four thicknesses for specimens of the 40/50/10 layup - 9, 27, 49, 73 plies. Four replicates were used for each combination of layup and thickness. Specimens were impacted by a free-falling steel impactor of 1 in. diameter and with a hemispherical end. During impact, specimens were sandwiched between a 1 in. thick steel bottom plate and a 0.25 in. thick aluminum plate, clammped by four corner bolts. Both plates had a central 5 in. x 5 in. opening whose center was aligned with those of the specimen and the impactor. The impactor, upon rebound, was caught thus avoiding subsequent impact. The resulting dent depths were measured with a dial gage and an ultrasonic through transmission method determined the damaged area extent. All testing was performed at room temperature. Specimens were not moisture preconditioned. Author

N93-21525# Thrace Univ., Xanthe (Greece). School of Engineering.

THE INFLUENCE OF PARTICLE/MATRIX DEBONDING ON THE STRESS-STRAIN BEHAVIOR OF PARTICULATE COMPOSITES

E. E. GDOUTOS *In* AGARD, Debonding/Delamination of Composites 9 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03

A mathematical model to predict the nonlinear stress-strain behavior of particulate composites is proposed. The model consists of a rigid circular or square inclusion embedded in a matrix across part of its boundary, while the remaining part forms an interfacial crack. The stress field in the composite plate is determined by using the theory of complex potentials in conjunction with the conformal mapping technique. The local stress field in the vicinity of the crack tip is of mixed-mode and it is governed by the values of the opening-mode and sliding-mode stress intensity factors. Initiation of debonding along the inclusion/matrix interface and growth of the interfacial crack is studied by using the maximum circumferential stress criterion. It is shown that the nonlinear behavior of the stress-strain diagram of particulate composites can be explained by studying the stable growth of the interfacial crack along the inclusion boundary. Author

N93-21526# Patras Univ. (Greece). Dept. of Mechanical Engineering.

IDENTIFICATION OF DELAMINATION BY EIGENFREQUENCY DEGRADATION: AN INVERSE PROBLEM

B. STAMOS, V. KOSTOPOULOS, and S. A. PAIPETIS *In* AGARD, Debonding/Delamination of Composites 7 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03

The free vibrations of a delaminated composite beam is investigated. The effect of interply delaminations on the eigenfrequencies of the beam is evaluated both analytically and numerically in the general case of an asymmetric laminate with a delamination of arbitrary size and location. Coupling between longitudinal and bending motion is considered, which affects the natural frequencies of the delaminated beam significantly. In general the delamination causes the even numbered vibration modes to degrade, e.g. to decrease, faster than the odd ones. An inversion method to determine position and size of the delamination is proposed, based on the degradation of the first two natural frequencies. Author

N93-21527# National Aero- and Astronautical Research Inst., Amsterdam (Netherlands).

INVESTIGATION OF THE BOND STRENGTH OF A DISCRETE SKIN-STIFFENER INTERFACE

H. G. S. J. THUIS and J. F. M. WIGGENRAAD *In* AGARD, Debonding/Delamination of Composites 9 p (SEE N93-21507 07-24) Dec. 1992
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This paper presents the results of an experimental study on the effects of several design parameters on the strength of a skin-stiffener interface. Design parameters which are considered are skin and stiffener laminate properties and the width of the bond layer. Test specimens consisting of a blade type stiffener secondarily bonded to skin laminate were fabricated. The specimens were tested by lateral tension tests, four-point bending tests and pull off tests. Calculations were made with the numerical program BONDST. The test results are compared with each other and with the calculated results. Conclusions are drawn and design guidelines are provided. Author

N93-21530# Bristol Univ. (England). Dept. of Aerospace Engineering.

PREDICTION OF DELAMINATION IN TAPERED UNIDIRECTIONAL GLASS FIBRE EPOXY WITH DROPPED PLIES UNDER STATIC TENSION AND COMPRESSION

MICHAEL R. WISNOM *In* AGARD, Debonding/Delamination of Composites 7 p (SEE N93-21507 07-24) Dec. 1992 Sponsored in part by Westland Helicopters Ltd.
(Contract(s)/Grant(s): SRC-GR/G19572)
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The mechanism of delamination in tapered unidirectional specimens with dropped plies is discussed. Results from six sets of static tests with different numbers of dropped and continuous

plies are presented. Specimens with 2 dropped/4 continuous, 2 dropped/8 continuous, and 6 dropped/4 continuous plies were tested in tension, and specimens with 2 dropped/16 continuous, 2 dropped/32 continuous, and 4 dropped/32 continuous plies were tested in compression. In all cases failure occurred by delamination into the thick section both above and below the dropped plies. Results are compared with predictions from a simple formula based on the strain energy release rate associated with the terminating plies, with the fracture energy determined from tension tests on a unidirectional specimen with cut central plies. Good correlation was found, and this approach is recommended as a design method for predicting delamination in tapered sections. Author (revised)

N93-21531# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).
ALLOWABLE COMPRESSION STRENGTH FOR CFRP-COMPONENTS OF FIGHTER AIRCRAFT DETERMINED BY CAI-TEST
J. BAUER, G. GUENTHER, and R. NEUMEIER *In* AGARD, Debonding/Delamination of Composites 6 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03
A test set-up was developed for CAI tests allowing coupon sizes from 300 x 100 up to 300 x 250 mm and thicknesses from 4 to 8 mm. The test set-up was approved to measure the residual compression strength after impact in accordance with other test methods e.g. the 'Boeing Test' and 4-point bending boxes. The test set-up is applicable for the investigation of all relevant test parameters and provides in addition to current test procedures the possibility to vary the geometric dimensions, width and thickness, in a wide comfortable range. This performance emphasizes its application for data collection and subsequent Design Allowables derivation. The experience with the Damage Tolerance aspects during the development of a fighter aircraft demonstrates that it is possible to introduce and consider impact requirements in the structural design phase. Author (revised)

N93-21532# Defence Research Establishment Pacific, Victoria (British Columbia).
REPAIRING DELAMINATIONS WITH LOW VISCOSITY EPOXY RESINS
A. J. RUSSELL and C. P. BOWERS (National Defence Headquarters, Ottawa, Ontario.) *In* AGARD, Debonding/Delamination of Composites 10 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03
Although resin injection is the procedure most often specified for repairing delaminations, field experience as well as numerous experimental investigations have shown it to be unreliable and in many cases ineffective. This paper identifies some of the reasons for this and then goes on to describe the successful development of an epoxy resin specially formulated for delamination repair. The ability of this resin to fully restore the out-of-plane properties of delaminated carbon/epoxy laminates is demonstrated, and some of the more practical aspects of repairing delaminations both on and off aircraft are discussed. Author (revised)

N93-21533# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany).
NUMERICAL DETERMINATION OF THE RESIDUAL STRENGTH OF BATTLE DAMAGED COMPOSITE PLATES
T. SCHNEIDER, J. MOEWS, and M. ROTHER *In* AGARD, Debonding/Delamination of Composites 16 p (SEE N93-21507 07-24) Dec. 1992 Sponsored by Ministry of Defence Original contains color illustrations
(AGARD-CP-530) Copyright Avail: CASI HC A03/MF A03
High energy impact damage by projectiles is a permanent threat to all aircraft or helicopters in combat situations. Besides the actual damage extent, caused by the incident, and its effect on airworthiness, the question of the residual strength of the damaged structure arises. Based on the experimental findings on the damage extent in shot-affected APC2/AS4 composite plates, a theoretical prediction of the residual compressive strength is given in terms of strength, stability, and fracture mechanics principles. These predictions are compared with test results from four specimens, which were cut out from the original plates. It will be shown, that the delaminations, caused by the high energy impact, triggered the final compressive failure of the specimens with the start of an unstable delamination growth and that this event can be correctly predicted by a numerical analysis, if local out-of-plane deformations are taken into account. Author (revised)

N93-21534# Deutsche Airbus G.m.b.H., Bremen (Germany).
EFFECT OF IMPACTS ON CFRP STRUCTURES, RESULTS OF A COMPREHENSIVE TEST PROGRAM FOR PRACTICAL USE
I. KROEBER *In* AGARD, Debonding/Delamination of Composites 10 p (SEE N93-21507 07-24) Dec. 1992 Sponsored in part by Volkswagen Foundation
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03
An experimental investigation was performed to establish the influence of impacts on the medium-tough CFRP material Ciba 6376/HTA. The results of this program enable a designer to dimension CFRP components. The compressive strain during impact was determined as a function of impact and impact energy. Slight increases of this compressive strain above a certain threshold resulted in catastrophic failure. Furthermore the influence of the thickness on residual strength and visible damage threshold is given. It was found, that the allowable strain limit not only depends on the impact energy but also on the laminate lay-up, especially the proportion of 0 degree-plies. Drop weight impacts show lower C-Scan damage areas compared with air gun impacts. However, the residual strain is the same in both cases. As opposed to coupons, stringer stiffened panels result in a scale-up effect of 15 percent concerning the allowable strain limit. However, this effect might change for different geometries. Author (revised)

N94-11317# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
SMART STRUCTURES FOR AIRCRAFT AND SPACECRAFT [LES STRUCTURES INTELLIGENTES POUR LES AERONEFS ET LES VAISSEAUX SPATIAUX]
Apr. 1993 387 p The 75th meeting was held in Lindau, Germany, 5-7 Oct. 1992
(AGARD-CP-531; ISBN-92-835-0701-X; AD-A267992) Copyright Avail: CASI HC A17/MF A04
An overview of the state-of-the-art of 'Smart Structures' technology as well as detailed descriptions of specific applications is presented. This technology offers extremely attractive advantages in the design, development, and operation of aerospace structures. For individual titles, see N94-11318 through N94-11347.

N94-11322# Massachusetts Inst. of Tech., Cambridge, MA. Space Engineering Research Center.
INTELLIGENT STRUCTURES: A TECHNOLOGY OVERVIEW AND ASSESSMENT
EDWARD F. CRAWLEY and MAC VICAR *In* AGARD, Smart Structures for Aircraft and Spacecraft 16 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04
A topical review of a decade of work toward the development of intelligent structures is presented, i.e., structures with highly distributed actuators, sensors, and processors. The background and status of the research in this area are covered, as are the evolution of the technology components: strain actuators, acceleration and strain sensors, processors and signal conditioning, and control algorithms. The results of several system level experimental implementations are presented, as are the challenges for further development. Author

N94-11324# Strathclyde Univ., Glasgow (Scotland). Optoelectronics Div.
OPTICAL FIBRE TECHNIQUES FOR STRUCTURAL MONITORING IN COMPOSITES
W. CRAIG MICHIE, B. CULSHAW, and D. UTTAMCHANDANI *In* AGARD, Smart Structures for Aircraft and Spacecraft 9 p (SEE N94-11317 01-24) Apr. 1993 Sponsored in part by BRITE/OSTIC
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The sensor technology to be used in smart structures must be compatible both operationally and mechanically with the material and the functional specification of the smart structure system. Fiber optic sensors are particularly attractive since they are mechanically robust and flexible. An overview of work which was carried out within the University of Strathclyde concerning the

development of fiber optic sensing techniques for use in structural monitoring applications for composite material systems is presented. Author (revised)

N94-11325# Strathclyde Univ., Glasgow (Scotland). Smart Structures Research Inst.

SMART PROCESSING OF COMPOSITE MATERIALS FOR ENHANCED PERFORMANCE AND PROPERTIES

A. MCDONACH, R. PETHRICK, and P. GARDINER *In* AGARD, Smart Structures for Aircraft and Spacecraft 6 p (SEE N94-11317 01-24) Apr. 1993

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There have been a large number of technologies described whose purpose is to aid in the control of composite manufacture. The aim of this paper is to readdress the requirements of composite manufacture to assess which features of the various techniques are best suited to providing improved processing. To start with, the requirements of quality in manufacture and the hidden costs associated with incorrect processing are considered. This will allow us to rank the aspects of processing which it would be attractive to improve. Following this, a range of monitoring processes and their ability to deliver on these improvements and at what cost in terms of expense and complexity are considered. Monitoring processes considered include fiber-optic (optical) methods, dielectrometry, and ultrasonic methods. Author

N94-11326# Aastra Aerospace, Inc., Downsview (Ontario).

SMART STRUCTURES AT AASTRA CORPORATION

D. R. UFFEN, H. SCHOLAERT, and G. SCHMID *In* AGARD, Smart Structures for Aircraft and Spacecraft 8 p (SEE N94-11317 01-24) Apr. 1993 Sponsored in part by Canadian Space Agency and Defence Research Establishment

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Aastra Advanced Ceramics is a major manufacturer of piezoelectric ceramic materials. Aastra Aerospace is involved in the development of smart structures technology based on these materials. Piezoelectric ceramics as actuators offer high mechanical stiffness, large output stress, and good linearity. As strain sensors, piezoceramics offer very high sensitivity. Initial research into the use of externally-bonded or embedded piezoceramic strain sensors and actuators has lead to the development of in-line sensor-actuator systems for use in truss-type smart structures. The target applications for these units are large flexible space structures, but the technology is applicable to earth-based truss structures as well. Similarly, Aastra is investigating the use of piezoelectric materials for the active damping of aircraft structures, with the goal of reducing structure-borne cabin noise with minimum additional weight. The development of Aastra's piezoceramic research activities and an overview of present work in the field of smart structures is presented. Author (revised)

N94-11327# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.

FIBER OPTIC SENSING FOR COMPOSITE SMART STRUCTURES

RAYMOND M. MEASURES *In* AGARD, Smart Structures for Aircraft and Spacecraft 43 p (SEE N94-11317 01-24) Apr. 1993 Sponsored in part by Ontario Laser and Lightwave Research Centre; Natural Sciences and Engineering Research Council; Inst. for Space and Terrestrial Science; and Ontario Centre for Materials Research

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Structurally integrated fiber optic sensors (SIFORS) will form a necessary part of future Smart Structures and strain sensing will provide valuable information on the use and loading of such structures and also determine the response of the structure to these loads. Strain measurements may be used to check structural integrity and in the case of Smart Adaptive Structure they would provide the deformation information required by the structurally integrated actuation control system. Continuous monitoring of the applied loads could also be used to determine the actual fatigue life of the structure at any point in its operation. In the case of composite materials improved quality control during fabrication may be possible from such a built-in sensing system and this could lead to a more consistent and reliable product. Overall the introduction of an embedded fiber optic strain sensing system to composite structures may enhance confidence in their use and lead to an expansion in the range of application, especially as primary structures in the aerospace field. The types of fiber optic sensors are reviewed and it is shown that the intracore Bragg grating and the intrinsic Fabry-Perot interferometer appear to qualify for continued consideration as the universal sensor for the broad range of potential Smart Structures. The key elements of strain sensing with both types of structurally integrated fiber optic sensors are reviewed and issues such as thermally induced apparent strain are discussed. It is shown that although both sensors now have good methods of demodulation, the Bragg grating sensor has the greatest potential to satisfy the requirements demanded of the ideal sensor for Smart Structures due to the recently developed radiometric wavelength demodulation system. This system promises the fabrication of a robust, simple, absolute measurement, low cost multisensor system that could be integrated onto an optoelectronic chip that can form part of the interface to any structure and in essence solve the critical interconnect problem. Two important questions, however, remain to be addressed: can the intracore Bragg grating sensor perform all of the tasks required, and can Bragg gratings of 'sufficient quality' be fabricated in an automated process. Author (revised)

N94-11328# Alenia Spazio S.p.A., Turin (Italy).

STRAIN MEASUREMENT OF CARBON/EPOXY COMPOSITE WITH FIBRE OPTICS WHITE LIGHT QUASI DISTRIBUTED POLARIMETRIC SENSOR

B. FORNARI, J. J. GUERIN (Bertin et Cie., Aix-les-Milles, France.), P. SANSONETTI (Bertin et Cie., Aix-les-Milles, France.), M. LEQUIME (Bertin et Cie., Aix-les-Milles, France.), and G. ROMEO (Politecnico di Torino, Italy.) *In* AGARD, Smart Structures for Aircraft and Spacecraft 3 p (SEE N94-11317 01-24) Apr. 1993

(Contract(s)/Grant(s): BRITE/EURAM-0173)

(AGARD-CP-531) Copyright Avail: CASI HC A01/MF A04

The results obtained in measuring the static and dynamic strain of carbon/epoxy composites with embedded or bonded fiber optics white light quasi-distributed polarimetric sensor are reported. Linear and accurate measurements were obtained and up to six sensing zones were parallely interrogated along a single optical fiber. Author (revised)

N94-11329# Technische Hogeschool, Twente (Netherlands). Lab. for Material Science.

ON THE STABILITY OF SHAPE MEMORY MATERIALS AND THEIR PROPERTIES IN STATIC AND DYNAMIC APPLICATIONS

J. BEYER and M. CHANDRASEKARAN *In* AGARD, Smart Structures for Aircraft and Spacecraft 7 p (SEE N94-11317 01-24) Apr. 1993

(AGARD-CP-531) Copyright Avail: CASI HC A02/MF A04

Shape memory materials form one group of 'smart materials' which are of current interest. The sensing and actuating performance of these shape memory materials have been used in diverse industrial applications. These applications involve either the one-way or two-way effect, pseudoelasticity, recovery forces or damping characteristics of the SM-alloy. Each of these characteristics is associated with its unique response to thermal-mechanical forces. Besides these material parameters, the operating conditions and design parameters have to be taken into account when structures, in which SM elements are incorporated, are to be considered. The processing as well as subsequent operating conditions are relevant to the reproducible (stable) behavior and life time of the material and are discussed. Author (revised)

N94-11331# Martin Marietta Corp., Denver, CO. Astronautics Group.

ADAPTIVE STRUCTURE DESIGN EMPLOYING SHAPE MEMORY ACTUATORS

MOHAN S. MISRA, BERNIE CARPENTER, and BRIAN MACLEAN *In* AGARD, Smart Structures for Aircraft and Spacecraft 6 p (SEE N94-11317 01-24) Apr. 1993

(AGARD-CP-531) Copyright Avail: CASI HC A02/MF A04

Shape memory alloy wire 'tendons' can be used as embedded actuator elements to control the level of facesheet strain in adaptive structural components which utilize sandwich panel construction. As facesheet strain is varied, the degree of curvature and magnitude of tip deflection of a panel section can be controlled. Methods for modeling and conditioning shape memory materials and their subsequent integration into composite structures are described

along with related control system and feedback sensor development. Finally, an adaptive antenna application employing 'flex-biased' actuation and an attitude control surface based on 'antagonistic' actuation are described. Author (revised)

N94-11336# Westland Aerostructures Ltd., East Cowes (England).
FACTORS AFFECTING THE EMBEDDING OF OPTICAL FIBRE SENSORS IN ADVANCED COMPOSITE STRUCTURES
N. C. EATON, M. J. CURRAN, J. P. DAKIN (Southampton Univ., England.), and H. GEIGER (Southampton Univ., England.) *In* AGARD, Smart Structures for Aircraft and Spacecraft 14 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

Composite materials offer tremendous benefits for engineering applications and are now specified for use in several safety critical structures. However, despite extensive materials research and development, they do have a number of areas where their behavior is still not fully understood. This is particularly so with the more complex mechanical parameters in larger structures. Current structural design attempts to allow for these unknowns by over-designing, extensive testing, and frequent inspection. Embedded optical fiber sensors offer the potential to monitor many of these parameters, and are additionally of a similar physical and mechanical nature to the reinforcement fibers used in advanced composites. Westland Aerospace was involved in the development of fiber sensors for composite monitoring for over five years, and pioneered the application of embedded fiber sensors in thermoplastic composites during earlier joint research projects with the United Technologies Research Center. Previous programmers showed that research and development into both optical fiber sensors and materials is a key to the success of 'smart structures' technologies. The BRITE sponsored Optical Sensing Techniques in Composites (OSTIC) program represents the largest European research program to date. Similar research is underway at several centers worldwide, mainly in the USA and Canada. It was decided to set up a joint sensors/materials project under the UK Government supported LINK Structural Composites collaborative research program. The project will be performed by Westland Aerospace and the Optical Fibre Sensors Group at the UK Optoelectronics Research Centre. Factors relating to the development and application of optical fiber strain sensors for the monitoring of composite structures, and in particular the factors relating to the embedding of these optical fibers in composite laminates are addressed. Author (revised)

N94-11337# Canadian Marconi Co. Ltd., Montreal (Quebec).
FIBER-OPTIC SENSOR SYSTEMS FOR MEASURING STRAIN AND THE DETECTION OF ACOUSTIC EMISSIONS IN SMART STRUCTURES
F. A. BLAHA and S. L. MCBRIDE (Acoustic Emission Monitoring Services, Inc., Montreal, Quebec.) *In* AGARD, Smart Structures for Aircraft and Spacecraft 11 p (SEE N94-11317 01-24) Apr. 1993 Sponsored in part by Dept. of Defence and Canadair Ltd.
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

The requirements of a fiber-optic strain sensor system for aircraft smart structures are outlined, and an experimental system developed by Canadian Marconi Company for this application is reported. Fiber-optic strain sensors were mounted on an aircraft undergoing full-scale durability and damage tolerance tests, the results of which are presented. Tests were also carried out to verify the response of fiber-optic sensors to acoustic impulse signals. Input signals, similar to the ones encountered in damaged materials under stress, were used to evaluate the response of the sensor to bulk, surface, and plate waves. This was done in order to assess the performance of fiber-optic sensors employed in the acoustic detection of damage in materials.
Author (revised)

N94-11343# Wright Lab., Wright-Patterson AFB, OH. Structures Div.
AIRCRAFT SMART STRUCTURES RESEARCH IN THE USAF WRIGHT LABORATORY
GREGORY S. AGNES and KEVIN SILVA *In* AGARD, Smart Structures for Aircraft and Spacecraft 9 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A02/MF A04

For several years, the Air Force Wright Laboratory has been investigating smart structures technologies. Smart structures incorporate active materials into structural components. Active materials either sense their environment or change in response to an external stimulus or both, and also should be able to carry loads. A smart structure is thus capable of sensing and/or reacting to its environment. Smart structures research at Wright Laboratory has mainly concentrated on aircraft sensory structures and multi-functional structures, such as integrated antennae (i.e., smart skins). Several major programs were initiated to apply and demonstrate these technologies. Recently, the ability of active materials (piezoceramics, for example) to control aircraft structures for improved performance and longevity, has received attention as well. The smart structures technologies are categorized as sensory, active, or multi-functional. The current state of the art for each area and programs aimed at exploiting smart technologies for aircraft applications are described. Gaps in the current technology are identified. Author (revised)

N94-11344*# Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA.
ADVANCES IN ADAPTIVE STRUCTURES AT JET PROPULSION LABORATORY
BEN K. WADA and JOHN A. GARBA *In* AGARD, Smart Structures for Aircraft and Spacecraft 13 p (SEE N94-11317 01-24) Apr. 1993 Sponsored by NASA, Washington
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

Future proposed NASA missions with the need for large deployable or erectable precision structures will require solutions to many technical problems. The Jet Propulsion Laboratory (JPL) is developing new technologies in Adaptive Structures to meet these challenges. The technology requirements, approaches to meet the requirements using Adaptive Structures, and the recent JPL research results in Adaptive Structures are described.
Author (revised)

N94-11346# Institut Superieur de Technologie (Luxembourg).
ACTIVE DAMPING AUGMENTATION OF ELASTOMECHANICAL SYSTEMS USING PIEZOELECTRIC SENSORS AND ACTUATORS
RAYMOND FREYMANN and EDMOND STUEMPER *In* AGARD, Smart Structures for Aircraft and Spacecraft 12 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

It will be shown how use can be made of piezoelectric elements, integrated as sensors and actuators in a closed control loop, to improve the modal damping behavior of elastomechanical systems. Focus is pointed on some special characteristics of piezoelectric elements, such as their dynamic behavior, their energy transfer capabilities when being used as actuators, and their geometric filtering possibilities when being used as sensors. The experimental part of the work concentrates on the active damping augmentation in the low frequency range of a flexible beam-shaped structural system with a total length of 4 meters. Author (revised)

N94-36649# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
CHARACTERISATION OF FIBRE REINFORCED TITANIUM MATRIX COMPOSITES [LA CARACTERISATION DES MATERIAUX COMPOSITES A MATRICE DE TITANE RENFORCES PAR FIBRES]
Feb. 1994 260 p In ENGLISH and FRENCH The 77th Meeting was held in Bordeaux, France, 27-28 Sep. 1993 Original contains color illustrations
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The combination of stiffness, strength, and high temperature resistance provided by fiber reinforced titanium matrix composites offers major benefits for aircraft engine and airframe applications,

N94-36657# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Materials Dept.
FIBRE-MATRIX INTERFACE PROPERTIES IN TI-MATRIX COMPOSITES: CHEMICAL COMPATIBILITY AND MICROMECHANICAL BEHAVIOUR
A. VASSEL, R. MEVREL, J. P. FAVRE, and J. F. STOHR *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 11 p (SEE N94-36649 12-24) Feb. 1994 Sponsored by Defence Research Establishment, Toronto
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

Silicon carbide reinforced titanium alloys or titanium aluminides are challenging materials for engine discs applications in the temperature range 650-800 C. The main problems concerning fiber-matrix compatibility, i.e. fiber coating degradation through diffusion controlled mechanisms and fiber-matrix mechanical behavior are reviewed based on recent studies. It is also shown how two micromechanical tests, the fragmentation and the push-out test may be correlated. With the help of a 1D shear-lag type model, taking fiber-matrix debonding into account, a good fit is obtained between measured and computed values of the fiber-matrix load-transfer mean shear-stress. Author

N94-36658# Naval Air Warfare Center, Warminster, PA. Aircraft Div.
OXIDATION BEHAVIOR OF TITANIUM ALUMINIDE MATRIX MATERIALS
JEFFREY COOK, EUN U. LEE, WILLIAM E. FRAZIER, THU-HA T. MICKLE, and JEFFREY WALDMAN *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 12 p (SEE N94-36649 12-24) Feb. 1994 Sponsored by ONR
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

Oxidation tests were performed on titanium aluminide alloys of three different compositions to determine their oxidation properties under isothermal and cyclic conditions. The TiAl/Ti3Al alloy and the Al3Ti exhibited roughly parabolic behavior between 900 and 1100 C, while the TiAl oxidized in a linear fashion. Rate constants and activation energies were calculated for each material, and based on these the rate-controlling processes and mechanisms were determined. Author

N94-36659# Dayton Univ. Research Inst., OH.
METHODOLOGIES FOR THERMAL AND MECHANICAL TESTING OF TMC MATERIALS
GEORGE A. HARTMAN and DENNIS J. BUCHANAN *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 9 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

An overview of test techniques currently being used at the Air Force Materials Directorate/MLLN laboratories for elevated temperature testing of TMC materials is presented. Methods for test system alignment/specimen gripping, specimen heating, temperature measurement, and displacement measurement are discussed in detail. In some cases, the interdependence of choices made in each of these areas is also discussed. A description of a complete system used to perform a variety of thermal and mechanical tests on TMC materials is presented. Selected results from tests using this system with TMC materials are presented. Author

N94-36660# Dayton Univ. Research Inst., OH.
ULTRASONIC NONDESTRUCTIVE CHARACTERIZATION METHODS FOR THE DEVELOPMENT AND LIFE PREDICTION OF TITANIUM MATRIX COMPOSITES
PRASANNA KARPUR, DAVID A. STUBBS, THEODORE E. MATIKAS, MARK P. BLODGETT, and S. KRISHNAMURTHY *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 12 p (SEE N94-36649 12-24) Feb. 1994
(Contract(s)/Grant(s): F33615-89-C-5612; F33615-91-C-5606; F33615-92-C-5663)
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

Titanium matrix composites (TMC's) are currently being developed for high strength and high stiffness applications with improved elevated operating temperature behavior. In order to provide guidelines for the development of new TMC's with the desired properties and to ensure reliable use, a thorough understanding of material behavior is required which necessitates the development and use of appropriate nondestructive evaluation (NDE) methods. This work outlines the concurrent use of NDE during composites development as well as material behavior studies of TMC's. The paper presents results based on various ultrasonic techniques developed in the Materials Directorate, Wright Laboratory of the U.S. Air Force for the evaluation of different aspects of development and use of TMC's to tailor the properties for a particular application. Author (revised)

N94-36661# Defence Research Agency, Farnborough, Hampshire (England).
METAL MATRIX COMPOSITES: ANALYSIS OF SIMPLE SPECIMENS AND MODEL COMPONENTS UNDER CREEP AND FATIGUE LOADING
G. F. HARRISON, B. MORGAN, P. H. TRANTER, and M. R. WINSTONE *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 15 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

The paper presents the results of a limited test program to establish the mechanical behavior of titanium metal matrix composite (MMC) laboratory specimens under tensile, low cycle fatigue (LCF), and creep loading conditions at 600 C. Using a micromechanical model, finite element stress analyses have been undertaken to evaluate local stresses under the various loading conditions. Good agreement was obtained only after the inclusion of procedures to calculate the residual stresses induced in cooling from the composite consolidation temperature to the test temperature. Additionally, as part of a collaborative component evaluation study, model discs manufactured by Rolls-Royce plc have been subjected to spin testing. These LCF results have been correlated via a macromechanical model which accounts for the orthotropic behavior of the MMC reinforced region of the disc. Author

N94-36662# Wright Lab., Wright-Patterson AFB, OH.
RESIDUAL STRENGTH AND LIFE PREDICTION TECHNIQUES FOR TI MMC
J. HARTER, D. HARMON, and R. POST *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 6 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

To date, the fatigue crack growth behavior of metal matrix composites (MMC) has been generally limited to data obtained from relatively small coupons (approximately 150 mm x 25 mm). Although self similar crack growth has been observed in some cases, many observers have noted various complex crack growth phenomena. Behaviors such as fiber bridging and extensive crack branching have been reported in several papers. The purpose of this paper is to present the results of several static and crack growth tests on larger titanium based MMC center cracked coupons (406 mm x 63.5 mm). The use of larger specimens has allowed for more observations during stable crack growth and is much more representative of actual applications. Author

N94-36663*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PROCESS/COMPOSITE CONCURRENT TAILORING OF SIC/TI COMPOSITES
C. C. CHAMIS and D. A. SARAVANOS *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 7 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

Recent work on the prediction of optimal processing and material characteristics for improved fatigue behavior of metal and intermetallic matrix composites (MMC's/IMC's) is summarized. The method is incorporated into the MMLT (Metal Matrix Laminate Tailoring) code. Excellent correlations between predictions for the isothermal fatigue life of the SCS-6/Ti-24Al-11Nb composite and experimental data are obtained at various temperatures and stress ranges. Finally, the optimal processing conditions for improved isothermal fatigue life of the composite are evaluated and the attained isothermal fatigue life improvements are shown. Author (revised)

where these materials could be used to reduce weight or improve performance. This workshop on the subject of characterization of titanium composites was intended to provide a forum for the exchange of information in this important area. Characterization in this case refers to the understanding of the behavior of the composites as it relates to the ability to predict their performance in real-life applications. It covers various topics that include mechanical test techniques, NDE methods, life prediction models, and other factors that will affect the level of confidence with which these relatively new materials will be accepted for application. For individual titles, see N94-36650 through N94-36670.

N94-36650# Wright Lab., Wright-Patterson AFB, OH. Materials Directorate.
POSSIBILITIES AND PITFALLS IN AEROSPACE APPLICATIONS OF TITANIUM MATRIX COMPOSITES
JAMES M. LARSEN, STEPHAN M. RUSS, and J. WAYNE JONES *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 21 p (SEE N94-36649 12-24) Feb. 1994 Sponsored by Systran Corp.
(Contract(s)/Grant(s): AF PROJ. 2302)
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

High-temperature, light-weight materials represent enabling technology in the continued evolution of high-performance aerospace vehicles and propulsion systems being pursued by the U.S. Air Force. In this regard, titanium matrix composites (TMC's) appear to offer unique advantages in terms of a variety of weight-specific properties at high temperatures. However, a key requirement for eventual structural use of these materials is a balance of mechanical properties that can be suitably exploited by aircraft and engine designers without compromising reliability. An overview of the current capability of titanium matrix composites is presented, with an effort to assess the balance of properties offered by this class of materials. Emphasis is given to life-limiting cyclic and monotonic properties and the roles of high-temperature, time-dependent deformation and environmental effects. An attempt is made to assess the limitations of currently available titanium matrix composites with respect to application needs and to suggest avenues for improvements in key properties. Author

N94-36651# McDonnell-Douglas Corp., Saint Louis, MO.
APPLICATIONS OF TITANIUM MATRIX COMPOSITE TO LARGE AIRFRAME STRUCTURE
TIMOTHY M. WILSON *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 31 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

Advanced Titanium Matrix Composite (TMC) materials are being developed for structures that must withstand high temperatures, possess high stiffness and be lighter. Scale-up of the TMC material system from the laboratory environment to large structural components has required significant advancements in design, manufacturing and assembly technology. Numerous large scale, TMC components have been developed, fabricated and tested to verify the feasibility of structural/material concepts for hypersonic vehicles. These articles include thick laminate TMC wing structure, minimum gage TMC fuselage sections, and integrated TMC fuselage/cryogenic tank structure. A summary of the development and testing of these articles is presented. Author (revised)

N94-36652# Textron Specialty Materials, Lowell, MA.
SCS-6 (TM) FIBER REINFORCED TITANIUM
JIM HENSHAW *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 6 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

The low weight structurally efficient SCS-6 Fiber Reinforced Titanium, as produced by Textron Specialty Materials, is a material awaiting the development of production applications. A multitude of airframe and engine parts have been produced for test and developmental purposes and a production facility has been established to fabricate preforms, intermediary products, and component shapes. Author

N94-36653# AEA Technology, London (England).
PROCESSING OF TITANIUM MATRIX COMPOSITES
E. A. FEEST and J. COOK *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 9 p (SEE N94-36649 12-24) Feb. 1994 Prepared in cooperation with United Kingdom Atomic Energy Authority, Harwell, England
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

European experience in the processing of monofilament reinforced Ti matrix composites is briefly reviewed. Results on fiber coating developments on foil- and PVD-based processing routes are presented. Issues addressed include fiber handling, fiber property measurement, residual stresses in fiber and matrix, fiber coating formulation and deposition, MMC consolidation, and composite properties. Progress towards economically viable matrix deposition via sputter ion plating is reported. Author

N94-36654# Academy of Sciences (USSR), Moscow (USSR). Inst. of Aviation Materials.
COMPOSITES BASED ON TITANIUM WITH EXTERNAL AND INTERNAL REINFORCEMENT
A. I. KHOREV *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 8 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

The possibility of the efficient increase of the specific elasticity modulus and the specific strength of materials as well as aerospace vehicles by means of developing composites based on titanium with external and internal reinforcement was considered. Author

N94-36655# British Petroleum Co. Ltd., Sunbury-on-Thames (England). Research and Engineering Centre.
MANUFACTURE AND PROPERTIES OF SIGMA FIBRE REINFORCED TITANIUM
J. G. ROBERTSON *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 8 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

Titanium Matrix Composites have long been known to offer potential for use in aeroengine components. The cost of producing the fiber and fabricating components has delayed large scale developments because of concern over long term component costs. The slow development pace has, in turn, kept the fiber and composite price high through low demand. Composite manufacturing routes using foil and filament wound fiber has been used for many years. The difficulties of maintaining a suitable fiber distribution during hot isostatic pressing and the availability of cheap foil have effectively put this technique on the shelf. However excellent fiber distributions have been achieved even in difficult geometries by a BP proprietary process. Mechanical properties comparable with the most expensive routes can be achieved with this, one of the cheapest manufacturing routes. Author

N94-36656# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. for Materials Science.
PROPERTIES OF TMC PROCESSED BY FIBRE COATING AND HIPING
H. J. DUDEK and R. LEUCHT *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 7 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

SiC-fiber reinforced titanium alloys (Ti6A14V and IMI834) were processed by fiber coating and hot isostatic pressing (HIPing). Composites with a well consolidated microstructure, with a fiber volume fraction between 0.2 to 0.6, with a narrow fiber distance distribution and a fine globular grain structure were obtained. Tensile properties according to the rule of mixture are measured with values of the ultimate tensile strength for the 0.4 SiC-Ti6A14V-composite of 2.4 GPa at room temperature and for the 0.37 SiC-IMI834-composite of 1.3 GPa at 900 C. Fatigue properties were measured under loading conditions of $R = -1$. Different crack initiation effects for different matrix properties and stress amplitudes were observed. Author

N94-36664*# Massachusetts Univ., Lowell, MA. Dept. of Mechanical Engineering.
MICROMECHANICAL MODELING OF DAMAGE GROWTH IN TITANIUM BASED METAL-MATRIX COMPOSITES
JAMES A. SHERWOOD and HOWARD M. QUIMBY *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 9 p (SEE N94-36649 12-24) Feb. 1994
(Contract(s)/Grant(s): NCC3-218)
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

The thermomechanical behavior of continuous-fiber reinforced titanium based metal-matrix composites (MMC) is studied using the finite element method. A thermoviscoplastic unified state variable constitutive theory is employed to capture inelastic and strain-rate sensitive behavior in the Timetal-21s matrix. The SCS-6 fibers are modeled as thermoplastic. The effects of residual stresses generated during the consolidation process on the tensile response of the composites are investigated. Unidirectional and cross-ply geometries are considered. Differences between the tensile responses in composites with perfectly bonded and completely debonded fiber/matrix interfaces are discussed. Model simulations for the completely debonded-interface condition are shown to correlate well with experimental results. Author

N94-36665# Birmingham Univ. (England). School of Metallurgy and Materials.
CRACK GROWTH UNDER CYCLE LOADING IN FIBRE REINFORCED TITANIUM METAL MATRIX COMPOSITES
P. BOWEN *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 16 p (SEE N94-36649 12-24) Feb. 1994 Sponsored by Science Research Council; Rolls-Royce Ltd.; and British Petroleum Co. Ltd.
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

This review paper considers the experimental characterization of crack growth from unbridged defects in fiber reinforced titanium metal matrix composites subjected to cyclic loading by the use of fracture mechanics parameters. The conditions under which parameters such as the nominal applied stress intensity range, Delta-K(sub app), the nominal maximum stress intensity factor, K(sub max), and the effective stress intensity range, Delta-K(sub eff), are of use, and their experimental measurement are considered. Effects of fiber fracture, stress intensity factor range, mean stress, loading configuration (bending versus tension), test temperature, and fiber-matrix interfacial strength on fatigue crack growth resistance are highlighted. Finally, a possible approach to the prediction of crack arrest in such composites is outlined. Author (revised)

N94-36666*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PREDICTION OF THERMAL AND MECHANICAL STRESS-STRAIN RESPONSES OF TMC'S SUBJECTED TO COMPLEX TMF HISTORIES
W. S. JOHNSON and M. MIRDAMADI *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 6 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

This paper presents an experimental and analytical evaluation of cross-plied laminates of Ti-15V-3Cr-3Al-3Sn (Ti-15-3) matrix reinforced with continuous silicon-carbide fibers (SCS-6) subjected to a complex TMF loading profile. Thermomechanical fatigue test techniques were developed to conduct a simulation of a generic hypersonic flight profile. A micromechanical analysis was used. The analysis predicts the stress-strain response of the laminate and of the constituents in each ply during thermal and mechanical cycling by using only constituent properties as input. The fiber was modeled as elastic with transverse orthotropic and temperature-dependent properties. The matrix was modeled using a thermoviscoplastic constitutive relation. The fiber transverse modulus was reduced in the analysis to simulate the fiber-matrix interface failures. Excellent correlation was found between measured and predicted laminate stress-strain response due to generic hypersonic flight profile when fiber debonding was modeled. Author

N94-36667# AEA Technology, London (England).
PRE-STANDARDISATION WORK ON FATIGUE AND FRACTURE TESTING OF TITANIUM MATRIX COMPOSITES
J. H. TWEED, J. COOK, N. L. HANCOX, R. J. LEE, and R. F. PRESTON *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 10 p (SEE N94-36649 12-24) Feb. 1994 Sponsored by Dept. of Trade and Industry
(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

This paper presents work on development of test techniques for S-N fatigue, fatigue crack growth, and fracture toughness of titanium matrix composites. Work has concentrated on eight-ply unidirectional Ti-6-4/SM1240 from BP Metal Composites with some preliminary work on eight-ply unidirectional Ti-6-4/SCS-6 from Textron Speciality Materials. For S-N fatigue testing, an approach, used successfully for the Textron material, consistently gave failures in the tab region for BP material. Transverse fracture toughness of Ti/SiC sheets has been determined using a double cantilever beam test. Care has to be taken to restrain specimen twisting. For two BP materials, the transverse fracture toughness correlated with the static strength values. Author

N94-36668*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ASTM AND VAMAS ACTIVITIES IN TITANIUM MATRIX COMPOSITES TEST METHODS DEVELOPMENT
W. S. JOHNSON, D. M. HARMON, P. A. BARTOLOTTA, and S. M. RUSS *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 17 p (SEE N94-36649 12-24) Feb. 1994
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

Titanium matrix composites (TMC's) are being considered for a number of aerospace applications ranging from high performance engine components to airframe structures in areas that require high stiffness to weight ratios at temperatures up to 400 C. TMC's exhibit unique mechanical behavior due to fiber-matrix interface failures, matrix cracks bridged by fibers, thermo-viscoplastic behavior of the matrix at elevated temperatures, and the development of significant thermal residual stresses in the composite due to fabrication. Standard testing methodology must be developed to reflect the uniqueness of this type of material systems. The purpose of this paper is to review the current activities in ASTM and Versailles Project on Advanced Materials and Standards (VAMAS) that are directed toward the development of standard test methodology for titanium matrix composites. Author (revised)

N94-36669# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry (France).
DEVELOPMENT OF MECHANICAL TESTING METHODS FOR TITANIUM MATRIX COMPOSITES (TRACTION-OGLIGO-CYCLIC FATIGUE) [DEVELOPPEMENT DE METHODES D'ESSAIS MECANIQUES POUR CMM A BASE TITANE (TRACTION-FATIGUE OLIGOCYCLIQUE)]
B. DAMBRINE and M. HARTLEY *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 15 p (SEE N94-36649 12-24) Feb. 1994 In FRENCH Original contains color illustrations
(AGARD-R-796) Copyright Avail: CASI HC A03/MF A03

The performance objectives proposed for the next generation of military engines (thrust/mass ratio approximately equals 15) suggest extreme conditions of usage of titanium alloys in the compressor discs, while not allowing any consideration for the mass objectives. The composite materials with metal matrices (titanium base matrix reinforced by long fibers of silicon carbide) exhibit characteristics that appear to be encouraging for the construction of compressor discs (rigidity, endurance at high temperature). A complete understanding of the characteristics of fiber reinforced titanium matrix composites is a qualifying condition to the initiation and to the validation of calculation methods on the expected life of the components. The first step is to study their conduct, on laboratory samples, while in a state of traction or oligo-cyclic fatigue. The elements leading to the development of the tests are presented. Transl. by FLS

N94-36670# National Physical Lab., Teddington (England). Div. of Materials Metrology.

MODELLING AND TESTING FIBRE REINFORCED TITANIUM FOR DESIGN PURPOSES

L. N. MCCARTNEY *In* AGARD, Characterisation of Fibre Reinforced Titanium Matrix Composites 10 p (SEE N94-36649 12-24) Feb. 1994

(AGARD-R-796) Copyright Avail: CASI HC A02/MF A03

A review is given on some aspects of designing with continuous fiber reinforced titanium alloys. Issues that are addressed are as follows: (1) Need for multiaxial constitutive relations describing behavior of fiber reinforced titanium for monotonic loading at different temperatures, unloading at different temperatures, cyclic changes in load and temperature both in and out of phase, and general thermomechanical loading. Linear, yielding, incremental plasticity and time dependent deformations are considered. (2) Need for reliable failure criteria that take account of the micromechanisms that contribute to the failure event. (3) Role that micromechanical modeling can play in the development of reliable constitutive relations and design methods. (4) Need for validated test methods to measure the parameters that appear in the constitutive relations that are used for design purposes. Author (revised)

N95-20655# Thomson-CSF, Paris (France). Div. Radars et Contre-Mesures.

COMPOSITE CASES FOR AIRBORNE ELECTRONIC EQUIPMENT: A TECHNOLOGY STUDY AND EMC [BOITIERS COMPOSITES POUR EQUIPEMENTS ELECTRONIQUES AEROPORTES: UNE ETUDE TECHNOLOGIQUE ET CEM]

B. DUMONT, J. LECUELLET, S. LAFORET, G. LABAUNE, and M. CAPLOT *In* AGARD, Advanced Packaging Concepts for Digital Avionics 12 p (SEE N95-20631 06-06) Oct. 1994 In FRENCH

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

The goal of this paper is to present work related to the development (study, fabrication, qualification) of a box and a bonnet cover out of composite materials intended for airborne electronic equipment on fighter aircraft. Work was undertaken with a double objective: assess mass characteristics compared to a metal case and obtain equivalent electromagnetic shielding performance. The technological step is presented: choice of materials and the processes of fabrication, mechanical and electromagnetic dimensioning. The methods of manufacture are described; they made it possible to obtain the desired characteristics. The metal composite material elements are currently being used on fighter aircraft. Transl. by CASI

N95-20656# Sextant Avionique, Valence (France).

LIGHTWEIGHT ELECTRONIC ENCLOSURES USING COMPOSITE MATERIALS

C. SARNO *In* AGARD, Advanced Packaging Concepts for Digital Avionics 12 p (SEE N95-20631 06-06) Oct. 1994 Sponsored by Ministry of Defence

(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

The ever increasing demand in technical and economical performances improvement of aircrafts has a direct incidence for avionics. Except microelectronic integration, the enclosures have a high potential of evolution. The main advantages of composite materials over metals in forming electronic enclosure are: reduction of weight (minimum 30 percent), better resistance to corrosion, improved fatigue and impact resistance, achievement of complex shapes, and low coefficient of thermal expansion. The main problems to be solved in extending the application of the use of composite materials to the field of airborne electronic equipments are to: provide adequate electromagnetic shielding, ensure survival in harsh thermal and mechanical environments, and achieve global competitivity of the final products. Different technologies have been considered: injection molding of short fibers reinforced thermoplastic for small sized equipments (V less than 21), pressure molding of graphite and glass reinforced thermosets for ATR case families, and metal matrix composites. This paper will address the main investigations that have been undertaken in France since 1986 in the first two fields covering both manufacturing and evaluation results. Author

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INORGANIC AND PHYSICAL CHEMISTRY

Includes chemical analysis, e.g., chromatography; combustion theory; electrochemistry; and photochemistry.

N92-27486# Centre National de la Recherche Scientifique, Chatenay-Malabry (France).

THE COHERENT FLAMELET MODEL FOR PROPULSION APPLICATIONS

D. VEYNANTE (Centre National de la Recherche Scientifique, Annecy-le-Vieux (France).), F. LACAS (Centre National de la Recherche Scientifique, Annecy-le-Vieux (France).), P. BOUDIER (Institut Francais de Petrole, Grenoble.), B. DILLIES (Centre National de la Recherche Scientifique, Annecy-le-Vieux (France).), J. M. SAMANIEGO (Centre National de la Recherche Scientifique, Annecy-le-Vieux (France).), T. POINSOT (Centre National de la Recherche Scientifique, Annecy-le-Vieux (France).), and S. CANDEL *In* AGARD, CFD Techniques for Propulsion Applications 14 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by SNECMA and DRET

(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06

This article reports our recent progress in the modeling of turbulent combustion for propulsion applications. The description of the reactive flow relies on the flamelet concept and uses a transport equation for the flame surface density. The coherent flamelet description which has evolved from a series of numerical and experimental studies is first reviewed and its recent improvements are explained. We then focus on the premixed version of the model. Two applications of relevance to aeronautical propulsion are then described. The first concerns a flame stabilized by a hot stream of combustion products. The second deals with a ramjet configuration comprising two lateral injection jets. In both cases, the model predictions are compared with experiments. It is shown that the model provides viable representations of these two cases. Author

N93-17614# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.

EXPERIMENTAL ANALYSIS OF COMBUSTION OSCILLATIONS WITH REFERENCE TO RAMJET PROPULSION

M. N. R. NINA and G. P. A. PITA *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 8 p (SEE N93-17607 05-20) Sep. 1992

(AGARD-CP-526) Copyright Avail: CASI HC A02/MF A03

The influences of flow rate, fuel air ratio, and bluff body geometry on the predominant frequencies of combustion-driven oscillations were measured in a tube and disc combustor. Small shifts in major frequencies were observed for different stabilizer geometries. By changing mass flow rate and at high velocities by changing the F/A ratio, discrete jumps in the frequency of large amplitude oscillations were produced in some of the configurations. Measurements of the wall pressure oscillations amplitude along the cold duct, upstream from the flameholder, confirm the presence of an acoustic three quarter wave. Changes in the cold cut length implies a difference in the main frequency of the pressure oscillations spectrum that was found to agree with the difference between two acoustic 3/4 waves corresponding to the two tube lengths. Author

N94-29246# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

FUELS AND COMBUSTION TECHNOLOGY FOR ADVANCED AIRCRAFT ENGINES [LES PROPERGOLS ET LES SYSTEMES DE COMBUSTION POUR LES MOTEURS D'AERONEFS]

Sep. 1993 495 p In ENGLISH and FRENCH Symposium held in Fiuggi, Italy, 10-14 May 1993 Original contains color illustrations

(AD-A275679; AGARD-CP-536; ISBN-92-835-0719-3) Copyright Avail: CASI HC A21/MF A04

The conference proceedings contains 38 papers that cover new technologies for low NO(x) combustors and advanced high pressure/high temperature cycle engines. The technical evaluation report and the keynote address are included at the beginning,

and discussions follow most papers. The symposium was arranged in the following sessions: technology overview papers (two papers); modeling: pollutant formation (four); modeling: combustor design (five); high temperature fuels and fuel systems (six); combustion research: performance (six); combustion research: emissions (five); fuel atomization: diagnostics and modeling (five); and combustion research: flowfield and mixing (four). The last paper is a contribution from Russia not allocated to a session. For individual titles, see N94-29247 through N94-29285.

N94-29248# Naval Air Warfare Center, Trenton, NJ. Aircraft Div.
COMBUSTION TECHNOLOGY NEEDS FOR ADVANCED HIGH PRESSURE CYCLE ENGINES
STEPHEN D. CLOUSER and RICHARD A. KAMIN *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 8 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

The challenges in designing high performance aircraft combustion systems have not changed significantly over the years, but the approach has shifted towards a more sophisticated analytical process. Initially an overview of the U.S. Navy's component technology development procedure is presented to show how technology development is still tied into mission requirements. A more technical discussion on combustion technology status and needs will show that the classic impediments that have hampered progress towards near-stoichiometric combustion still exist. Temperature rise, mixing, liner cooling, stability, fuel effects, temperature profile control, and emissions continue to confront the aerodynamic and mechanical designers with a plethora of engineering dilemmas and trade-offs. In addition, new materials such as ceramic matrix composites (CMC) and intermetallics like titanium aluminides (TiAl) are now being incorporated into every advanced design. The process of combustion design has taken on a new meaning over the past several years as three dimensional codes and other advanced design and validation tools have finally changed the approach from a 'cut and burn' technique to a much more analytical process. All of these new aspects are now integral elements of the new equation for advanced combustion design that must be fully understood and utilized. Only then will the operable, high temperature capable combustion systems needed for future military aircraft be developed. Author

N94-29249# Rolls-Royce Ltd., Bristol (England).
COMBUSTION FOR FUTURE SUPERSONIC TRANSPORT PROPULSION
B. W. LOWRIE *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 6 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

Even with it's marginal performance, Concorde has demonstrated that supersonic civil aircraft are a practical proposition. A second generation machine will need sufficiently good performance for a robust operating system that can provide reliable, frequent service with competitive economics. Additionally, the propulsion system must be acceptable environmentally. That is it must create acceptable noise levels around airports and have acceptable emissions throughout its mission including cruise. Whatever devices may be used to improve the acceptability at subsonic flight conditions, the high operating temperatures at cruise can create difficult targets for the operation of the combustion system both mechanically and in the combustion process itself. While the driving force is ever better fuel consumption and weight to achieve economic viability, a future supersonic transport engine will have cycle temperatures limited only by the mechanical integrity of the major components. The environment of the major components in modern gas turbine engines is dominated by the air delivered by the compressor system. Consequently the maximum compression temperature is governed by materials available for the turbine and compressor discs. The continued improvement of the disc material leads to combustion inlet temperatures beyond today's experience and sets difficult targets for combustion system emissions. This is worsened by the requirement being at cruise and therefore maintained for the major part of the mission. Problems such as creep and oxidation of metallic parts are also considered. Author (revised)

N94-29250# Leeds Univ. (England). Dept. of Fuel and Energy.
PREDICTION OF PROMPT NO(X) IN HYDROCARBON AIR FLAMES
VALERIE DUPONT, M. POURKASHANIAN, and A. WILLIAMS *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 13 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

The gas turbine industry is directing particular attention to very low NOx combustors, whether for aircraft or land based CCGT systems. These low NOx combustors frequently use liquid fuels or natural gas burning under very lean premixed conditions with air or under rich-lean conditions, although only the first case is studied here. In land based systems, diluted steam or nitrogen are sometimes injected into the combustion chambers to reduce flame temperature. The NOx emissions from such systems are the product of three chemical mechanisms which are interrelated: the hydrocarbon prompt NO, the thermal NO (extended Zeldovich mechanism), and the nitrous oxide route to NO. Formation of NO2 from NO also occurs, as well as emission of carbon monoxide and unburnt hydrocarbons. When the fuel-oxidant proportion decreases towards leaner conditions, flame temperatures are lowered, resulting in the total NO being reduced and the thermal-NO contribution greatly diminished to the benefit of the remaining two mechanisms of NO formation. While knowledge of the elementary reactions and their chemical kinetics concerning methane and simple hydrocarbons combustion has existed for a number of years, its use for computer modeling is limited to simple flow dynamics configurations. Nevertheless, understanding of such combusting flows under a wide range of experimental conditions allows for analogies or speculations with more complex actual systems. Such understanding can be achieved by means of one dimensional laminar premixed flame modeling, with a full chemical mechanism which incorporates the three routes of NO formation. Complementary to this understanding is the modeling of the actual combustion system using a full description of the fluid dynamics coupled with a reduced chemical scheme, which is then compared against the first model. The objective of this investigation is to evaluate the relative importance of the three mechanisms of NO formation in lean premixed methane-air combustion with increasing pressure using the one dimensional plug flow package PREMIX, and to test the validity of a three dimensional model with a global chemical mechanism against the one dimensional model in the atmospheric pressure case. Methane is chosen because it is the only mechanism which is reasonably well known and is a good guide to the behavior of other hydrocarbons. The mixture ratio chosen is richer than that in lean gas turbines, but the combustion of this mixture with the low preheat gives realistic gas turbine final flame temperatures. Conditions of NO2 formation are also analyzed in the one dimensional model and results extrapolated to the case of gas turbines. Derived from text

N94-29251# Centre National de la Recherche Scientifique, Paris (France).
SIMULATION OF POLLUTANT FORMATION IN TURBULENT COMBUSTORS USING AN EXTENDED COHERENT FLAME MODEL
E. DJAVDAN, D. VEYNANTE, J. M. DUCLOS, and S. CANDEL *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 8 p (SEE N94-29246 08-25) Sep. 1993
Sponsored by SNECMA
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An extension of a flame surface density model, combining flamelet concepts and homogeneous reactor combustion, is proposed to predict NO and CO formation. Results for CO in propane-air premixed flames for different equivalence ratios are compared to available experimental measurements. The agreement is good but the model is sensitive to the determination of the flamelet model parameters such as those governing the effective strain rate. Author (revised)

N94-29252# Cranfield Inst. of Tech., Bedford (England). School of Mechanical Engineering.
FLOWFIELD PREDICTION OF NO(X) AND SMOKE PRODUCTION IN AIRCRAFT ENGINES
S. ALIZADEH and J. B. MOSS *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 20 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by Science Research Council
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CFD predictions of nitric oxide and smoke production in a tubular combustor are described for a range of inlet temperature and pressure conditions up to 800 K and 8 bar, chosen to distinguish the effects of both state properties and turbulence on formation rates. Combustion models based on both laminar flamelet and chemical equilibrium representations are contrasted and compared with measurements in the literature. While uncertainties persist with respect to the detailed mechanisms, notably for soot formation, a strategy is identified which extends the role of mixture fraction in the calculation of the influence of turbulent scalar fluctuations on emissions prediction. Author (revised)

N94-29253# Technical Univ. of Lisbon (Portugal). Dept. of Mechanical Engineering.
NUMERICAL PREDICTION OF TURBULENT SOOTING DIFFUSION FLAMES
P. J. COELHO, T. L. FARIAS, J. C. F. PEREIRA, and M. G. CARVALHO *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 16 p (SEE N94-29246 08-25) Sep. 1993
(Contract(s)/Grant(s): BD/860/90-IB)
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

Soot formation is an important but poorly understood subject. Although significant advances have been made in the last few years, soot formation models for numerical calculation still present recognized shortcomings. Different soot formation models are compared in the calculation of a propane turbulent diffusion flame and the influence of soot agglomeration and refractive index on soot volume fraction values inferred from extinction measurements are investigated. The time-averaged equations governing conservation of mass and momentum are closed by the k-epsilon eddy viscosity/diffusivity model and combustion is modeled using the laminar flamelet approach. Soot prediction involves the solution of transport equations for soot particle number density and soot mass fraction. The uncertainties of soot volume fractions obtained from extinction measurements due to agglomeration and the value of the complex refractive index were studied. Results using Rayleigh approximation were compared with predictions using the model presented by Iskander et al. for scattering and extinction of light by an ensemble of spherical particles. Author (revised)

N94-29265*# Pennsylvania State Univ., University Park, PA. Dept. of Mechanical Engineering.
THE EFFECT OF INCOMPLETE FUEL-AIR MIXING ON THE LEAN LIMIT AND EMISSIONS CHARACTERISTICS OF A LEAN PREVAPORIZED PREMIXED (LPP) COMBUSTOR
D. A. SANTAVICCA, R. L. STEINBERGER, K. A. GIBBONS, J. V. CITENO, and S. MILLS *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 12 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by NASA. Lewis Research Center and GE
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

Results are presented from an experimental study of the effect of incomplete fuel-air mixing on the lean limit and emissions characteristics of a lean, prevaporized, premixed (LPP), coaxial mixing tube combustor. Two-dimensional exciplex fluorescence was used to characterize the degree of fuel vaporization and mixing at the combustor inlet under non-combusting conditions. These tests were conducted at a pressure of 4 atm., a temperature of 400 C, a mixer tube velocity of 100 m/sec and an equivalence ratio of .8, using a mixture of tetradecane, 1 methyl naphthalene and TMPD as a fuel simulant. Fuel-air mixtures with two distinct spatial distributions were studied. The exciplex measurements showed that there was a significant amount of unvaporized fuel at the combustor entrance in both cases. One case, however, exhibited a very non-uniform distribution of fuel liquid and vapor at the combustor entrance, i.e., with most of the fuel in the upper half of the combustor tube, while in the other case, both the fuel liquid and vapor were much more uniformly distributed across the width of the combustor entrance. The lean limit and emissions measurements were all made at a pressure of 4 atm. and a mixer tube velocity of 100 m/sec, using Jet A fuel and both fuel-air mixture distributions. Contrary to what was expected, the better mixed case was found to have a substantially leaner operating limit. The two mixture distributions also unexpectedly resulted in comparable NO(x) emissions, for a given equivalence ratio and inlet temperature, however, lower NO(x) emissions were possible in the better mixed case due to its leaner operating limit. Author

N94-29266# Dayton Univ., OH.
STUDIES OF LEAN BLOWOUT IN A RESEARCH COMBUSTOR
D. R. BALLAL, M. D. VANGSNESS, S. P. HENEGHAN, and G. J. STURGESS *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 9 p (SEE N94-29246 08-25) Sep. 1993
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(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

A prime requirement in the design of a modern gas turbine combustor is good lean blowout (LBO) stability to ensure an adequate stability margin. Therefore, a geometrically simple, optically accessible, and acoustically decoupled research combustor was designed to reproduce the gross features of the flow field in a modern annular gas turbine combustor. Its LBO was measured using methane and propane fuels. We successfully observed and documented a systematic and detailed sequence of events comprising an attached flame, a lifted shear flame, an intermittent shear flame, the large-scale instability of the flame front, and LBO. Also, for the sake of comparison, a generic gas turbine combustor was tested and its LBO limits were measured. We found that LBO in the research combustor behaved like a perfectly stirred reactor (PSR) for values of combustor-loading spanning three orders of magnitude. Also, LBO was successfully correlated using a simple PSR theory. Finally, Swithenbank's dissipation gradient approach and an eddy dissipation model with a built-in characteristic extinction time criterion, when coupled with CFD, offer the possibility of an a priori calculation of LBO. The lean stability of a generic gas turbine combustor at peak heat release rates was less than that in a research combustor. Also, in the generic combustor, the flame changes from a lifted to an attached position depending upon how combustor loading is achieved. Due to such complications, modeling of the LBO process that works reasonably well with the research combustor will be seriously challenged by the blowout behavior evidenced in the generic gas turbine combustor. Author

N94-29268# Centro Applicazioni Militari dell'Energia Nucleare, Pisa (Italy).
COMPUTATIONAL AND EXPERIMENTAL RESULTS IN HIGH PRESSURE COMBUSTIONS OF H2/AIR AND H2/O2/H2O
DINO DINI *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 10 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

The first results of a research and development program on combustion characteristics of gaseous hydrogen fuel in a 'can' type gas turbine combustor, both in combination with air or with oxygen and water, are here presented. Application of a H2/O2/H2O combustion chamber is suggested for the launch-boost phase of an advanced turboramjet. Experiments have been conducted to determine the configuration and the operation of the hydrogen-air combustion chamber test facility, to be transferred to two different kinds of small power turboshafts. Computations, project details and tests, are presented regarding high pressure and temperature stoichiometric H2/O2 combustion in which water is gradually injected. Referring to an already realized and operated (on behalf of the author) H2/O2/H2O combustor for a water steam closed cycle in a turbine/alternator electrically propelled automobile, a detailed design is developed for a quite higher steam temperature, as required in high performance boost phase of a low noxious emission advanced turboramjet, in which H2 and O2 are stored in liquid form. Author

N94-29271*# California Univ., Irvine, CA. Combustion Lab.
POLLUTANT EMISSIONS FROM AND WITHIN A MODEL GAS TURBINE COMBUSTOR AT ELEVATED PRESSURES AND TEMPERATURES
S. A. DRENNAN, C. O. PETERSON, F. M. KHATIB, W. A. SOWA, and G. S. SAMUELSEN *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 10 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by Northrop Corp.
(Contract(s)/Grant(s): NAG3-1124; F08635-90-C-0100)
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Conventional and advanced gas turbine engines are coming under increased scrutiny regarding pollutant emissions. This, in turn, has created a need to obtain in-situ experimental data at practical conditions, as well as exhaust data, and to obtain the data in combustors that reflect modern designs. The in-situ data are needed to (1) assess the effects of design modifications on pollutant formation, and (2) develop a detailed data base on combustor performance for the development and verification of computer modeling. This paper reports on a novel high pressure, high temperature facility designed to acquire such data under controlled conditions and with access (optical and extractive) for in-situ measurements. To evaluate the utility of the facility, a model gas turbine combustor was selected which features practical hardware design, two rows of jets (primary and dilution) with four jets in each row, and advanced wall cooling techniques with laser drilled effusive holes. The dome is equipped with a flat-vaned swirler with vane angles of 60 degrees. Data are obtained at combustor pressures ranging from 2 to 10 atmospheres of pressure, levels of air preheat to 427 C, combustor reference velocities from 10.0 to 20.0 m/s, and an overall equivalence ratio of 0.3. Exit plane and in-situ measurements are presented for HC, O2, CO2, CO, and NO(x). The exit plane emissions of NO(x) correspond to levels reported from practical combustors and the in-situ data demonstrate the utility and potential for detailed flow field measurements. Author

N94-29272# Pratt and Whitney Aircraft, East Hartford, CT.
REDUCTION OF NO(X) BY FUEL-STAGING IN GAS TURBINE ENGINES: A COMMITMENT TO THE FUTURE
I. SEGALMAN, R. G. MCKINNEY, G. J. STURGESS, and L.-M. HUANG *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 17 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

As part of an ongoing program of continuous improvement by control of gaseous emissions from the combustors of gas turbines, a unique fuel-staged annular combustor is being developed for application to current and future Pratt & Whitney aircraft engines. The configuration advantages of this combustor are outlined, and discussions are presented on staging considerations and fuel system impacts. Development of the fuel-staged combustor is described by reference to supporting mixing experiments and computational fluid dynamic studies, and rig tests at high pressures. Measured results are given appropriate for the International Aero Engines (IAE) V2500 engine that show progressive reductions in achieved emissions compared to the goals established for this program. Author

N94-29273# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Dept. YKC.
CHAMBERS OF TURBOREACTORS WITH VARIABLE GEOMETRY: A RESPONSE TO THE MATRIX OF POLLUTION IN CYCLES AT HIGH TEMPERATURE, HIGH PRESSURE [LES FOYERS DE TURBOREACTEURS A GEOMETRIE VARIABLE: UNE REPONSE A LA MAITRISE DE LA POLLUTION DANS DES CYCLES A HAUTE TEMPERATURE, HAUTE PRESSION]
S. MEUNIER, D. ANSART, and P. CICCIA *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 4 p (SEE N94-29246 08-25) Sep. 1993 In FRENCH
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The pollutants emissions decrease doesn't seem easily achievable, particularly with advanced engines cycles conditions with high pressure, temperature, and fuel to air ratio. For a given fuel and air split, the combustor size can't be reduced without leading to relight altitude, combustion stability, and emissions concerns. In addition, the liners areas to be cooled remain considerable, the cooling airflow increase leads to higher fuel to air ratio in the primary zone and finally to unacceptable Nox emissions levels due to higher flame temperatures. In order to satisfy the trade off in between the combustor performance at low and high engine ratings, several combustor concepts are in development. Among them, the use of variable geometries to modulate the primary zone airflow seems promotive. Indeed, this concept allows to satisfy the compromise between the different ratings taking into account the decrease of the combustor panels areas to be cooled. That is the reason why this variable geometry concept is particularly suitable to high pressure and temperature engines cycles. In this paper, test results recorded on a five-cups sector fitted with a variable geometry injection system, and some measured performance on a full annular combustor are commented. It appeared that acceptable performance in term of combustion stability can be met with a low volume combustor. The cooling airflow reduction and the primary zone fuel to air ratio control allow to meet quite good and homogeneous combustor exit temperature profiles whatever the engine rating. Author

N94-29274# Defence Research Agency, Farnborough, Hampshire (England).
THE INFLUENCE OF AIR DISTRIBUTION ON HOMOGENEITY AND POLLUTANT FORMATION IN THE PRIMARY ZONE OF A TUBULAR COMBUSTOR
J. R. TILSTON, M. I. WEDLOCK, and A. D. MARCHMENT *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 12 p (SEE N94-29246 08-25) Sep. 1993
(Contract(s)/Grant(s): BRITE/EURAM-1019)
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

This paper summarizes the work undertaken by the Defense Research Agency (DRA Pyestock) for the BRITE/EURAM Low Emissions Combustor Technology Project No 1019. The work was jointly funded by the CEC (DGXIIH), the UK DTI (CARAD - ATF4) and the UK MOD (DCSA). The gas turbine emissions problem is summarized and the design philosophy of the experimental program is described. The principal objective was to demonstrate a simultaneous reduction of NO(x) and smoke emissions together with acceptable idling emissions and stability in an unstaged combustor. A secondary objective was to demonstrate the extent to which NO(x) and smoke could be reduced if the combustor was to be used as the main stage of a staged combustor where a poorer idling performance could be accepted. The work consisted of a parametric investigation of the principal factors controlling the emissions produced in the combustor primary zone. Particular emphasis was placed on the influence of the distribution, number, and size of air entry holes and of residence time on pollutant formation. The results from the complete experimental program are summarized. These suggest that NO(x) reductions of about 30-40 percent should be possible together with excellent smoke and idling performance. The results suggest that NO(x) was formed very close to stoichiometric flame temperatures even at very weak combustor mixture strengths and under well mixed conditions. The reductions that were achieved were largely as a result of reductions of residence time. Author

N94-29275# Universidad Politecnica de Madrid (Spain). Dept. de Motopropulsion y Termofluidodinamica.
EFFECTS OF HYDROGEN ADDITION ON POLLUTANT EMISSIONS IN A GAS TURBINE COMBUSTOR
J. SALVA and G. LOPEZ *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 9 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

This paper presents an experimental work on the control of pollutants produced in a tubular hydrocarbon fueled combustor, by the injection of hydrogen in small quantities (less than 4 percent of total fuel). Hydrogen is introduced in the primary zone premixed with the air. Using this technique, with lean primary zone, it is possible to reduce the NO(x) emission level while maintaining CO and HC emission index at normal levels (CO and HC levels are greater without hydrogen injection). Injecting butane, instead of hydrogen, shows that there is no beneficial effect, so the influence of hydrogen in CO and HC reduction is due mainly to factors such as hydrocarbon substitution and chemical kinetics. An analysis to estimate the contribution of these factors is also included. Author

N94-29276# Imperial Coll. of Science and Technology, London (England). Dept. of Mechanical Engineering.
DUCTED KEROSENE SPRAY FLAMES
R. M. PEREZ-ORTIZ, S. SIVASEGARAM, and J. H. WHITELAW *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 16 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by Rolls-Royce Ltd.
(Contract(s)/Grant(s): N00014-89-J-1721)
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

Reaction progress in premixed methane-air flames in round ducts without and with kerosene sprays has been quantified on the basis of species concentration measurements for different fueling arrangements of kerosene with equivalence ratio, proportion of liquid to gaseous fuel, duct length and air preheat temperature as variables in smooth and in rough combustion. The intensity of heat release close to the flame holder in rough combustion was greater than that in smooth combustion, and the duct length necessary to ensure complete combustion decreased with air preheat temperature and upstream turbulence intensity and was weakly dependent on the proportion of methane to kerosene in flow arrangements where the kerosene was sprayed upstream of the flame-holder. The injection of kerosene through the flame holder at a velocity larger than that of the mean flow past the disk led to uneven mixing and incomplete combustion. Pulsed injection of kerosene through a pintle-type injector also resulted in incomplete combustion due to the larger droplet size than in arrangements with a steady flow of kerosene. Oscillations of large amplitude were induced at equivalence ratios usually associated with smooth combustion and oscillations in rough combustion ameliorated by pulsed injection of kerosene comprising around 10 percent of the total fuel. Author

N94-29277*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPRAY COMBUSTION EXPERIMENTS AND NUMERICAL PREDICTIONS
EDWARD J. MULARZ (Army Research Lab., Cleveland, OH.), DANIEL L. BULZAN, and KUO-HUEY CHEN *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 21 p (SEE N94-29246 08-25) Sep. 1993 Original contains color illustrations
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

The next generation of commercial aircraft will include turbofan engines with performance levels significantly better than those in the current fleet. Control of particulate and gaseous emissions will also be an integral part of the engine design criteria. These performance and emission requirements present a technical challenge for the combustor: control of the fuel and air mixing and control of the local stoichiometry will have to be maintained much more rigorously than with combustors in current production. A better understanding of the flow physics of liquid fuel spray combustion is necessary. This paper describes recent experiments on spray combustion where detailed measurements of the spray characteristics were made, including local drop-size distributions and velocities. Also, an advanced combustor CFD code has been under development and predictions from this code are compared with experimental results. Studies such as these will provide information to the advanced combustor designer on fuel spray quality and mixing effectiveness. Validation of new fast, robust, and efficient CFD codes will also enable the combustor designer to use than as valuable additional design tools for optimization of combustor concepts for the next generation of aircraft engines. Author

N94-29278# Centre d'Etudes et de Recherches, Toulouse (France).
MODELING OF THE PHASE LIQUIDATES IN COMBUSTION CHAMBERS [MODELISATION DE LA PHASE LIQUIDE DANS LES CHAMBRES DE COMBUSTION]
P. HEBRARD, G. LAVERGNE, P. BEARD, P. DONNADILLE, and P. TRICHET *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 12 p (SEE N94-29246 08-25) Sep. 1993 In FRENCH
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

This paper presents experimental results, numerical models, and simulations relating to the behavior of the liquid phase in combustion chambers. These studies concern the initial conditions, boundary conditions, and validations of the models of the various physical processes which must be integrated into the computer codes of reactive flows. Several experiments are presented: characterization of a jet of drops at the aerodynamic exit of a burner, dispersion of the drops in a screen turbulence and a strongly nonstationary flow, trajectories and evaporation of the drops in a turbulent flow, and interaction of the drops with a hot wall. The characterizations of the diphasic flows are carried out by LDA and hot wire for the gas phase and by phase Doppler anemogranulometry and rapid video techniques associated with image processing for the liquid phase. Video techniques and image processing make it possible to restore the trajectories of the drops, their speed as well as the main statistics of dispersion (average trajectory, envelope, and presence rate). The experimental results, in particular those coming from the dispersion of the drops, are compared with the numerical results of simulations. The Lagrangian method is used for transport of the drops, and their dispersion can be calculated starting from the following two approaches: the gas phase is calculated by direct simulation and a deterministic model is retained for the transport of the drops; and the gas phase is calculated starting from a model of turbulence of the type K- and stochastic models are used for the transport of drops. In conclusion, the models most appropriate to the diphasic flows studied are deduced. Author (revised)

N94-29279# Karlsruhe Univ. (Germany). Lehrstuhl und Inst. fuer Thermische Stroemungsmaschinen.
A NEW EULERIAN MODEL FOR TURBULENT EVAPORATING SPRAYS IN RECIRCULATING FLOWS
S. WITTIG, M. HALLMANN, M. SCHEURLEN, and R. SCHMEHL *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 11 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by Arbeitsgemeinschaft Hochtemperatur Gasturbine and DFG
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A new Eulerian model for the computation of turbulent evaporating sprays in recirculating flows is derived. It comprises droplet heating and evaporation processes by solving separate transport equations for the droplet's temperature and diameter. Full coupling of the droplet and the gaseous phase is achieved by the exchange of source terms due to momentum, heat, and mass transfer. The partial differential equations describing the droplet's transport and evaporation in the new method can be solved using the same numerical procedure as for the gas phase equations. The validity of the model is established by comparison with a well known Lagrangian approach and with experimental data. For this purpose calculations of a recirculating droplet charged air flow within a model combustor are presented.
Author (revised)

N94-29281# Technische Hochschule, Darmstadt (Germany). Flight Propulsion.
THE MIXING PROCESS IN THE QUENCHING ZONE OF THE RICH-LEAN-COMBUSTION CONCEPT
TH. DOERR and D. K. HENNECKE *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 9 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by DFG Original contains color illustrations
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

The rich burn/quick quench/lean burn (RQL) combustion system is a potential concept to reduce both NO(x) and CO, UHC emissions. In view of the concept's crucial mixing process, an experimental investigation of a nonreacting multiple jet mixing with a confined crossflow has been conducted. Temperature distributions, mixing rate, and standard deviation were determined for measurements with round jet orifices by parametric variation of flow and geometric conditions. The results show that best mixing strongly depends on an optimum momentum flux ratio. Too high ratios yield a deterioration of mixing process, due to the mutual impact of opposed entraining jets. Furthermore, over a wide range of geometries investigated, inline and staggered configurations provide similar mixing rates. An appreciable enhancement of mixing with staggered orifice configurations only occurs for high momentum flux ratios and large spacings. Author

N94-29284# Calgary Univ. (Alberta). Dept. of Mechanical Engineering.
TEMPERATURE AND COMBUSTION ANALYSIS OF COMBUSTOR WITH ACOUSTICALLY CONTROLLED PRIMARY ZONE AIR-JET MIXING
P. J. VERMEULEN, V. RAMESH, B. SANDERS, and J. ODGERS *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 13 p (SEE N94-29246 08-25) Sep. 1993
(Contract(s)/Grant(s): NSERC-A-7801)
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

A small tubular combustor of normal design and behavior, employing acoustically controlled primary zone air-jet mixing processes, has been successfully tested at scaled 1/4 load operating conditions, and some data was obtained at 1/2, 3/8, and 3/4 loads. The acoustic control produced a distinct richening effect, measured just downstream of the primary zone, which produced a decrease in combustion efficiency and a somewhat increased and flatter combustion gas temperature distribution. The prime cause of richening was due to combustor flow blockage caused by acoustically enhanced jet penetration. This, and the secondary effect of acoustically shed jet toroidal vortices, resulted in up to 35 percent increase in mixing, relative to 'no-drive' measured just downstream of the primary zone. The acoustic drive produced a more uniform exit plane temperature pattern, resulting in up to 35 percent improvement in mixing relative to 'no-drive' and in up to 20 percent relative improvement in the temperature pattern quality. The effects depend on air/fuel ratio and, in general, improved relative to 'no-drive' with richening. At 3/4 load, 150 W single driver power, the acoustic driving effectiveness was reduced by about 80 percent with correspondingly reduced improvements in mixing and quality. The effects of acoustic drive were favorably controllable by means of the driving power, and the exit plane data showed increased flow blockage caused by increased jet penetration by the acoustic drive was the major control mechanism. Author (revised)

N95-21081# Central Inst. of Aviation Motors, Moscow (Russia).
A FLAMELET MODEL FOR TURBULENT UNPREMIXED COMBUSTION
V. R. KUZNETSOV *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 10 p (SEE N95-21061 06-34) Dec. 1994
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04

Combustion theory is an applied science which is syntheses of several fundamental theories such as chemistry, heat and mass transfer theory, hydrodynamics, turbulence, etc. Now the knowledge of these theories is adequate to make calculations for practical purposes. However some difficulties still remain unresolved. The most important one is associated with the steep dependence of chemistry on temperature. As a result chemistry is confined to very thin zones (flamelets). Hence very large memory and speed of computers are needed to resolve flamelets in DNS. This difficulty is aggravated by the large number of intermediate species. The use of turbulence closures does not help since one has to assume that eddy diffusivities of reacting species and their pdf's (which are needed to average chemistry rates) are the same as that of conserved scalar. There are several examples indicating that these assumptions may lead to significant errors. Therefore there is a need to develop some new approach. Author

N95-21082# Manchester Coll. of Science and Technology (England). Dept. of Mechanical Engineering.
DIRECT NUMERICAL SIMULATION FOR PREMIXED TURBULENT COMBUSTION MODELLING
R. S. CANT *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 13 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by Stanford Univ., Shell Research Ltd., and the UK Science and Engineering Research Council
(AGARD-CP-551) Copyright Avail: CASI HC A03/MF A04

Recent advances in computer power have made it feasible to carry out Direct Numerical Simulation (DNS) of fundamental test problems in turbulent combustion. Nevertheless the requirements in terms of numerical grid resolution remain very severe and engineering computations will remain beyond the reach of DNS for some time to come. Thus there is an undiminished role for statistical modeling using traditional moment-closure techniques and DNS can be used to provide fundamental data in support of such modeling. The present paper describes a specific example of the use of DNS results to improve the quality of a well-established model of premixed turbulent combustion. A brief outline of the model formulation is given, followed by a short description of the DNS and post-processing techniques employed. Some results of immediate utility are presented in order to illustrate the usefulness of the approach, and the parameterization of some further data is discussed in detail. The significance of the main improvements to the modeling is indicated and some remaining limitations are discussed. The prospects for future model refinement by improved DNS are examined and found to be excellent. Author

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METALLIC MATERIALS

Includes physical, chemical, and mechanical properties of metals, e.g., corrosion; and metallurgy.

N94-37323# British Columbia Univ., Vancouver (British Columbia). Dept. of Metals and Materials Engineering.
ALTERNATE MELTING AND REFINING ROUTES
ALEC MITCHELL *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 8 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright Avail: CASI HC A02/MF A02

Although most research and development effort in turbine alloys has been in the past directed towards the understanding and improvement of basic properties, it is a telling comment on the results that at present we can only manufacture the components with a reliability which, in the example case of a high pressure turbine disk, leads to a service life of less than one-fifth of the theoretical life of the alloy component. The purpose of this presentation is to examine the reasons for this situation and to indicate ways in which we can improve on it. We conclude that the techniques of melting, refining and casting which are now being developed have the potential to make a large change in the in-service life of turbine components without any significant change in the state of alloy development. Author

N94-37324# Wright Lab., Wright-Patterson AFB, OH. Materials Dirctorate.
PROCESS ENHANCEMENTS OF SUPERALLOY MATERIAL
RONALD H. WILLIAMS, KRISTINE A. LARK, SHARON VUKELICH, DONALD R. PARILLE, and RICHARD W. SALKELD *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 6 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright Avail: CASI HC A02/MF A02

Due to the ever-increasing demand for improvements in engine performance and better fuel efficiency, complex high pressure turbine (HPT) blade designs have been introduced into military engines. Greater emphasis has, therefore, been placed on increasing the structural integrity and life of engine components. Materials defects must be of a small enough size and sparse enough in population to enable the design of high thrust-to-weight ratio engines. This requirement has demanded the industry attainment of cleaner materials. In order to meet this requirement, possible process improvements were evaluated. Enhancements were incorporated into the melting and casting processes to reduce the size and number of dross defects within high pressure turbine blades. The accomplishment of this goal was through the efforts of a joint United States Air Force, Pratt & Whitney Task Force Team. Process implementation has been successful in reducing the remaining deleterious defects present in directionally solidified single crystal and polycrystalline nickel-base superalloy turbine blade materials. In conjunction with the introduction of melting and casting process improvements, the refinement of non-destructive inspection techniques was investigated. Author

N94-37325# Imphy S.A., Imphy (France).
THE CONTROL OF CLEANNESS IN POWDER METALLURGY MATERIALS FOR TURBINE DISKS
G. RAISSON *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 14 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright Avail: CASI HC A03/MF A02

The origins of exogenous inclusions in powder metallurgy products are described and methodologies for assuring the quality of these alloys are reviewed. Elutriation, chemical dissolution, micrography, electron beam button melting, ultrasonic inspection, and other techniques are described and compared. CASI

N94-37326# Forge Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Gennevilliers (France).
MAINTAINING CONSTANT STANDARDS DURING THE FORGING PROCESS [MAITRISE DE LA REPRODUCTIBILITE DU PROCEDE DE FORGEAGE]
F. CHEVET and M. CARALP *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 23 p (SEE N94-37321 12-38) Apr. 1993 In FRENCH
(AGARD-R-790) Copyright Avail: CASI HC A03/MF A02

The properties of aircraft engine discs made of a titanium and nickel alloy may be notably improved if deformations and temperatures are monitored during the forging process. On engines of recent fabrication, this optimization through thermomechanical treatment is also systematically applied. As an answer to this need SNECMA is using a monitoring system in its metal processing plant: monitoring devices positioned on the heat deformation machinery record and statistically document the important parameters. This new monitoring system, taking place at the time of fabrication, makes it possible to immediately detect any variance in the fabrication and to rapidly correct any possible abnormality. Thus checking and ensuring total duplication of the fabrication becomes systematic and the quality control checks on the finished project (strongly linked to the conditions of transformation) have improved. Finally, because of the knowledge that was thus gained on the forging process, our command of the thermomechanical treatments was improved. Variations in parameters which were not recorded in the past and had an important influence on the microstructure of the parts were observed. Transl. by FLS

N94-37328# Defence Research Agency, Farnborough, Hampshire (England).
DEFECTS AND THEIR EFFECTS ON THE INTEGRITY OF NICKEL BASED AEROENGINE DISCS
G. F. HARRISON, P. H. TRANTER, and L. GRABOWSKI *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 16 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright Avail: CASI HC A03/MF A02

By specific reference to the powder metallurgy alloy API the paper examines the role of defects in generating local residual stress fields. The effects of defect size and location on crack initiation and low cycle fatigue life are discussed. It is shown that at stress levels consistent with those experienced by current engine components, defects can act under cyclic loading as crack nucleators from cycle 1. Methods of calculating appropriate stress intensity factors are briefly reviewed and it is shown that at existing turbine disc operating temperatures, a linear elastic fracture mechanics stress intensity factor can be used to calculate crack growth rates. Finally, the major lifting methods used for aeroengine discs are briefly reviewed, and attention is drawn to the specific problems created by the presence of macrostructural defects. Author

N95-19674# Liege Univ. (Belgium). Dept. Metallurgie et Science des Materiaux.
ANALYSIS OF THE EROSION OF CUBIC CENTERED AND FACE CENTERED METALLIC MATERIALS [ANALYSE DE L'EROSION DE MATERIAUX METALLIQUES DE STRUCTURES CUBIQUES CENTREE ET FACE CENTREE]
A. MAGNEE *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 13 p (SEE N95-19653 05-07) Nov. 1994 In FRENCH
(AGARD-CP-558) Copyright Avail: CASI HC A03/MF A03

A generalized law of erosion, in nondimensional form, is proposed. The aforementioned explicitly gives an account of the nature and the microstructure of the material impacted, the angle of impact of the particles, and their hardness. The erosion behavior of various steels, pig iron, and cast iron is examined as well as the behavior of new ordered intermetallic materials, Fe-25 percent Al-(Zr, Cr, B). The concern of such alloys in an erosion-corrosion environment is shown. Author

N95-19682# La Sapienza Univ., Rome (Italy). Dipt. di Chimica.
X-RAY ABSORPTION SPECTROSCOPY IN HIGH TEMPERATURE OXIDATION OF METALS AND ALLOYS
DANIELE GOZZI and MASSIMO TOMELLINI (Tor Vergata Univ., Rome, Italy.) *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 8 p (SEE N95-19653 05-07) Nov. 1994 Sponsored by Centro Sviluppo Materiali and Lab. Nazionali di Frascati
(AGARD-CP-558) Copyright Avail: CASI HC A02/MF A03

An experimental technique is described that allows for the joint study of the kinetics and of the oxide structure during the high temperature oxidation of metal surfaces. Oxygen is supplied at the metal through an electrochemical oxygen pump and the oxygen pressure, at the metal surface, is measured during oxidation by a YSZ (yttria stabilized zirconia) oxygen sensor. XAS (x-ray absorption spectroscopy) is performed in fluorescence mode at the cation K edge and after each oxidation step. An appropriate analysis of the XAS spectra could provide information on both the oxidation kinetics and oxide structure. Experimental data on the high temperature oxidation of nickel, cobalt, and Fe(64%)Ni(36%) alloy, at low oxygen pressure, are reported and analyzed according to the proposed data reduction. These results indicate the presented technique to be particularly suitable for studying the hot corrosion of oxide film too thick for common surface spectroscopy (AUGER, ESCA) and too thin for conventional thermogravimetric technique. Author

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NONMETALLIC MATERIALS

Includes physical, chemical, and mechanical properties of plastics, elastomers, lubricants, polymers, textiles, adhesives, and ceramic materials.

N94-11330# Pisa Univ. (Italy). Faculty of Engineering.
SMART POLYMERIC SYSTEM FOR ELECTROMECHANICAL TRANSDUCTION
P. CHIARELLI, D. DEROSSI, and KAYO UMEZAWA *In* AGARD, Smart Structures for Aircraft and Spacecraft 3 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A01/MF A04

The various mechanisms eliciting electromechanical response, in polymer gels and conducting polymers, which have been exploited to eventually develop electrically driven gel actuators are briefly reviewed. A few approaches undertaken to eventually obtain electrochemomechanical systems with better performance are indicated. Author (revised)

N94-24228# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
INTRODUCTION OF CERAMICS INTO AEROSPACE STRUCTURAL COMPOSITES [L'INTRODUCTION DES CERAMIQUES DANS LES COMPOSITES UTILISES DANS LES STRUCTURES DES SYSTEMES AEROSPATIAUX]
Nov. 1993 160 p In ENGLISH and FRENCH Workshop held in Antalya, Turkey, 21-22 Apr. 1993
(AGARD-R-795; AD-A276040; ISBN-92-835-0728-2) Copyright Avail: CASI HC A08/MF A02

Ceramics have been considered over the last two decades as a possible alternative to refractory metals and alloys to be used as structural materials for aeronautical use. The main disadvantage of these materials is their brittleness and the very low value of the critical size of defects leading to fracture. The concept of ceramic matrix composites has been recognized as one of the ways to escape this difficulty. Extensive work has been performed to identify the mechanisms of crack propagation and general fracture for unidirectional composites, laminates or other fabrics, including the understanding of their long term response: creep

and fatigue effects or environmental degradation. The Workshop which has been held by AGARD SMP at Antalya (Turkey), April 1993, aimed at reviewing the present knowledge on all these aspects. For individual titles, see N94-24229 through N94-24240.

N94-24229# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

AN OVERVIEW ON THE MAIN AVAILABLE CERAMIC COMPOSITES AND THEIR PROCESSING ROUTES

J. F. STOHR *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 16 p (SEE N94-24228 06-27) Nov. 1993
(AGARD-R-795) Copyright Avail: CASI HC A03/MF A02

During the last decade, Ceramic Matrix Composites (CMC) have undergone a rapid development, and today, quite a number of composites are available. SiC/SiC and C/SiC, processed by Chemical Vapor Infiltration (CVI), are now produced on an industrial scale. C/SiC composites can currently operate at temperatures above 1600 C for propulsion applications on launchers and missiles. Other composites with oxide or silicon-nitride matrices are under development. The processing routes are moving from CVI to more cost-effective processes such as sol-gel and polymer precursor. These routes appear very promising since they currently use the technologies already developed for Organic Matrix Composites and carbon-carbon composites. The real challenge for these materials is in the areas of the working temperature, which must exceed 1600C, and the environmental behavior. To meet these requirements, new fibers with an increased thermal stability are under development. Author (revised)

N94-24230# California Univ., Santa Barbara, CA. Dept. of Materials.

CERAMIC MATRIX COMPOSITES: CHALLENGES AND OPPORTUNITIES

A. G. EVANS *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 13 p (SEE N94-24228 06-27) Nov. 1993
(Contract(s)/Grant(s): N00014-86-K-0753)
(AGARD-R-795) Copyright Avail: CASI HC A03/MF A02

A methodology for the straightforward and consistent evaluation of the constituent properties of CMC's is summarized. The methodology is based on an analyses of current literature. The results provide a constitutive law capable of simulating the stress/strain behavior of these materials. The approach is illustrated using data for two CMC's: SiC/CAS and SiC/SiC. The constituent properties are also used as input to mechanics procedures that characterize stress redistribution and predict the effect of strain concentrations on macroscopic performance. Author

N94-24231# Wright Research Development Center, Wright-Patterson AFB, OH.

INTERFACE EVALUATION IN CERAMIC COMPOSITES

PAUL D. JERO, TRIPLICANE A. PARTHASARATHY, and RONALD J. KERANS *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 10 p (SEE N94-24228 06-27) Nov. 1993
(AGARD-R-795) Copyright Avail: CASI HC A02/MF A02

The results of pushout tests on two ceramic matrix composites are presented and discussed. Emphasis is placed on the effect of interface roughness on the interfacial properties. Toward that end, techniques used to characterize fiber and interface topography are described and results presented. An advanced analysis, which takes account of the roughness contribution to the radial stress during debonding, is used to calculate interfacial properties. It is observed that the fiber fabrication technique has a profound effect on the nature of the interfacial topography. Author

N94-24232# Wright Research Development Center, Wright-Patterson AFB, OH.

MICROMECHANICAL FAILURE MODES IN BRITTLE MATRIX COMPOSITES

NICHOLAS J. PAGANO *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 18 p (SEE N94-24228 06-27) Nov. 1993
(AGARD-R-795) Copyright Avail: CASI HC A03/MF A02

Ceramic-and glass ceramic matrix composites are being touted for application in high temperature structural components. Before their potential can be realized, however, understanding of the significance of the fracture modes that occur at very low stress levels well beneath those commonly assumed to initiate microcracking in the literature, will be essential. Unfortunately, at this point in the technology development, the precise definition of these mechanisms, i.e., the geography of the fracture plane(s), has been described rather incompletely in experimental research. In most cases, the experimental observations only provide views of these cracks at their intersection with a surface of the composite. Thus, in this presentation, we will provide some predictions of failure scenarios based upon a hypothetical idealized initial flaw in the matrix-an annular crack in a plane normal to the fibers of an unidirectional composite. Although many of the properties needed for the modeling study have not been realistically determined, especially the in-situ strength/ fracture properties, and the fracture criteria itself incorporates an undetermined parameter, i.e., initial flaw size, it is hoped that the modeling can serve to determine the nature of the parameters that require measurement and to help establish the sensitivity of the response to these parameters, as well as to guide experimental efforts to attempt validation of the failure processes hypothesized. The complexity of these processes seems to demand an iterative approach between the analyst and experimentalist. Derived from text

N94-24233# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Direction des Materiaux.

MICROMECHANICAL CHARACTERIZATION OF CERAMIC-MATRIX COMPOSITES USING THE INSTRUMENTED MICROINDENTATION TECHNIQUE [CARACTERISATION MICROMECANIQUE DES COMPOSITES A MATRICE CERAMIQUE A L'AIDE DE LA TECHNIQUE DE MICROINDENTATION INSTRUMENTEE]

M. PARLIER, B. PASSILLY, and O. SUDRE *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 8 p (SEE N94-24228 06-27) Nov. 1993 In FRENCH See also A93-53607
(AGARD-R-795) Copyright Avail: CASI HC A02/MF A02

The paper describes the potential of micromechanical studies using the instrumented Vickers indentation test in force and displacement. For ceramics reinforced by long fibers, it is possible to determine the hardness and the elastic modulus of the components as well as the mechanical characteristics of the fiber-matrix interface. Oxide and covalent (silicon carbide) matrix composites reinforced by SiC-Nicalon fibers are considered as examples. Author

N94-24234# Institut National des Sciences Appliquees, Lyon (France). Groupe d'Etudes de Metallurgie Physique et de Physique des Materiaux.

ROLE OF INTERFACES ON THE CYCLIC FATIGUE BEHAVIOUR OF CERAMIC MATRIX COMPOSITES

D. ROUBY and P. REYNAUD *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 10 p (SEE N94-24228 06-27) Nov. 1993 Sponsored by CNRS; Ministere de la Recherche et de l'Espace; Direction des Recherches, Etudes et Techniques; and CNES
(AGARD-R-795) Copyright Avail: CASI HC A02/MF A02

Ceramics reinforced with continuous fibers exhibit delayed failure under pulsating load. A micromechanical model describing the fatigue effects is proposed. It is based on the decreasing of the shear stress at the fiber-matrix interfaces, resulting from interfacial wear due to the see-saw sliding. The main features of this model are the following: during first loading cycle, the material exhibits multiple matrix cracking and some fiber breaks. During subsequent cycles, the interfacial shear stress decreases, leading to increasing the failure probability of the bridging fibers. For a critical fraction of broken bridging fibers, instability occurs and the specimen fails, thus, defining the lifetime. For lower peak stresses, but higher still than the proportionality limit, the material also evolves but no failure occurs (up to one million cycles), indicating that the interfacial shear stress decreases to a non-zero lower bound. Fatigue induced changes of interfacial shear stress are also observed from fiber pull-out length analyses. Author

N94-24235# Caen Univ. (France).
MECHANICAL BEHAVIOR OF CMCS: CRACK GROWTH RESISTANCE AND CREEP ASPECTS
M. GOMINA and J. L. CHERMANT *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 18 p (SEE N94-24228 06-27) Nov. 1993
(AGARD-R-795) Copyright Avail: CASI HC A03/MF A02
Rupture and creep behavior of ceramic matrix composites (CMC's) are discussed. The influence of the specimen geometry and size on the R-curve behavior for two types of SiC/C/SiC composite materials were investigated. The experimental results obtained using in-situ matrix crack lengths indicate that the shape of the resistance curve depends essentially on the predominant toughening mechanism (extensive matrix microcracking or fiber-matrix debonding) whereas the frontal process zone size is the same for both types of materials. K(sub R)-Delta(a) curves of SENB and small CT specimens rise as a consequence of the ligament which cannot contain the fully developed frontal process zone. Using large CT specimens, a minimum ligament size necessary to contain the frontal process zone and thus a K(sub R)-Delta(a) behavior free of structure size is observed. Creep results obtained using three point bending tests are also presented for these materials and for SiC-MLAS materials. Author (revised)

N94-24236# Warwick Univ., Coventry (England). Dept. of Physics.
MICROSTRUCTURE AND MICROMECHANICAL BEHAVIOUR OF CMCS
M. H. LEWIS, A. CHAMBERLAIN, A. M. DANIEL, M. W. PHARAOH, A. G. RAZZELL, and S. SUTHERLAND *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 13 p (SEE N94-24228 06-27) Nov. 1993 Sponsored by Science Research Council and Rolls Royce Ltd.
(AGARD-R-795) Copyright Avail: CASI HC A03/MF A02
A survey is presented of research aimed at an understanding of the relation between microstructure, interface properties, and macromechanical behavior of a range of silicate (glass ceramic) and nitride matrix composites. For silicate ceramic matrix composites (CMC's), hot-pressing cycle (P/T) in relation to matrix chemistry and fiber type is critical in avoiding mechanical and chemical damage of fibers with consequent reduction in ultimate CMC strength. Interfacial debond and shear stresses, measured via a fiber 'push-down' indentation technique exhibit a wide variation, dependent on CMC processing time, temperature and matrix chemistry and thermal expansion. 'Graceful' failure, typified by 3 stage stress-strain curves, may be obtained for debond energies Gamma and shear stresses tau up to approximately 20 Jm(sup -2) and approximately 50 MPa, respectively. Interface-oxidation-induced property degradation occurs at intermediate temperatures (400-800 C) but is suppressed at higher temperatures by passive oxidation of SiC fiber ends which prevents further carbon interface removal by channeled reaction. Higher temperature SiC (Textron CVD) monofilament based CMC's with Si3N4 (SRBSN) matrices were fabricated using tape-cast matrix preforms. Partially sacrificial C-coatings on the monofilaments provide low Gamma and tau interfaces and result in ideal composite response with separation between matrix cracking stress and ultimate stress, followed by filament pull-out. Although interface oxidation is a limiting problem for creep and stress rupture, these properties are superior to turbine superalloys. Author (revised)

N94-24237# Societe Europeenne de Propulsion, Saint-Medard-en-Jalles (France).
CERAMIC MATRIX COMPOSITE PARTS DESIGN
P. LAMICQ and D. BOURY *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 12 p (SEE N94-24228 06-27) Nov. 1993
(AGARD-R-795) Copyright Avail: CASI HC A03/MF A02
Ceramic matrix composites (CMC) are making up a new material family that presents a significant potential for thermostructure design. They show a good specific strength and stiffness up to high temperatures and these characteristics are associated to non-fragile behaviors which do correspond to the designer practical requirements. After a short description of the CMC most used by SEP designers, a thought on part design and dimensioning with these materials is presented. An approach of the currently used general methodology is presented, followed by various comments specific to the use of these materials. Finally, some examples of singular behaviors, which are currently poorly controlled by simple modeling and require advanced rupture criteria, are given.
Derived from text

N94-24238# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany). Inst. of Structures and Design.
CMC DESIGN CONSEQUENCES
W. KRENKEL *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 12 p (SEE N94-24228 06-27) Nov. 1993
(AGARD-R-795) Copyright Avail: CASI HC A03/MF A02
Ceramic matrix composites (CMC) have widely demonstrated their feasibility and performance although no series production has been achieved. Today's status is characterized by long production times, high material qualities with high reproducibility and experience in the first structural components. Some unsolved problems are the joining and attachment of CMC parts, the lack of adequate nondestructive testing methods and the insufficient oxidative stability for long term applications. This paper deals with general valid design aspects as a consequence of the CMC materials characteristics and the demand for structural components of high reliability. Author

N94-24239# Maschinenfabrik Augsburg-Nuernberg A.G., Munich (Germany).
INTEGRATED APPROACH IN MODELLING, TESTING, AND DESIGN OF GRADIENT-CVI DERIVED CMC COMPONENTS
D. SYGULLA, A. MUEHLRATZER, and P. AGATONOVIC *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 13 p (SEE N94-24228 06-27) Nov. 1993 Sponsored by BMFT
(AGARD-R-795) Copyright Avail: CASI HC A03/MF A02
Ceramic composite materials with continuous fibers in a SIC matrix, manufactured by CVI, have shown benefits for structural applications due to high fracture toughness and damage tolerance under operational conditions. However, the production time associated with the hitherto applied CVI technique entails development cycles of hardly acceptable long duration. Therefore, there is growing interest for the CVI technique to manufacture reliable CMC parts, focusing special attention on a more efficient production technology. In this paper a current attempt to develop and qualify a new CVI process, the so-called gradient-CVI, is described and discussed. This process offers increased productivity appropriate for industrial production and excellent material properties. Author

N94-24240# Wright Lab., Wright-Patterson AFB, OH. Materials Directorate.
ULTRASONIC NONDESTRUCTIVE EVALUATION AS A TOOL FOR THE DEVELOPMENT OF AEROSPACE STRUCTURAL CERAMIC COMPOSITES
THEODORE E. MATIKAS and PRASANNA KARPUR (Dayton Univ. Research Inst., OH.) *In* AGARD, Introduction of Ceramics into Aerospace Structural Composites 7 p (SEE N94-24228 06-27) Nov. 1993
(Contract(s)/Grant(s): F33615-89-C-5612)
(AGARD-R-795) Copyright Avail: CASI HC A02/MF A02
This paper outlines new concepts for the utilization of various ultrasonic techniques for the evaluation of different aspects of development and use of ceramic matrix composites. We introduce a novel mechanical parameter called the interfacial shear stiffness coefficient which can be measured using ultrasonic shear wave reflectivity technique to characterize and quantify the fiber-matrix interface. This newly proposed parameter is promising as a common basis of composite evaluation among the composites developing, composites mechanics modeling and composites testing groups. The paper will also discuss other ultrasonic NDE techniques such as ultrasonic microscopy which can provide comprehensive evaluation of the composite system during all phases of development and use. Derived from text

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PROPELLANTS AND FUELS

Includes rocket propellants, igniters, and oxidizers; their storage and handling procedures; and aircraft fuels.

N92-33240# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
INSENSITIVE MUNITIONS [LES MUNITIONS A RISQUE ATTENUE]
Jul. 1992 287 p In ENGLISH and FRENCH 78th Meeting held in Bonn, Fed. Republic of Germany, 21-23 Oct. 1991
(AGARD-CP-511; ISBN-92-835-0679-0; AD-A255698) Copyright Avail: CASI HC A13/MF A03

The papers presented reflect significant progress that has been made in understanding and characterizing the response of energetic materials to external stimuli such as shock, fire, and bullet impact. Small scale testing results, statistical data, and approaches to numerical modeling are reported. The need for deeper investigation of the mechanisms involved, for corroboration of the statistical results, and for better fidelity criteria of small scale testing becomes apparent. The NATO Insensitive Munitions Information Center (NIMIC), recently established in Brussels, is charged with providing more exchange of information and international cooperation. For individual titles, see N92-33241 through N92-33245.

N92-33241# Air Force Armament Lab., Eglin AFB, FL. Insensitive Munitions Directorate.
THE UNITED STATES AIR FORCE EXPLOSIVES HAZARDS REDUCTION PROGRAM
JOSEPH JENUS, JR. *In* AGARD, Insensitive Munitions 13 p (SEE N92-33240 23-28) Jul. 1992
(AGARD-CP-511) Copyright Avail: CASI HC A03/MF A03

The Air Force Insensitive Munitions/Explosives Hazard Reduction Program is discussed. Key initiatives are in the barriers and packaging area are covered. Barriers and packaging which can be designed to prevent the propagation of one munitions item to the next will reduce the Maximum Credible Event (MCE). Barriers can be placed inside or outside munitions containers or between bombs on parked aircraft. Simple changes to the way munitions are packaged, such as orienting missiles within a container so that warheads do not align, may also reduce the MCE. Effective barriers and packaging can limit the MCE to one munitions item in a magazine full of munitions or one bomb in a mission ready aircraft. This will also result in significant reductions in quantity-distances required and allow more munitions to be stored in closer proximity to airbases, flightlines, and hardened aircraft shelters, where they are needed. Author

N92-33242# Phillips Lab., Edwards AFB, CA. Propellant Development Section.
ESD TRAITS OF BULK PROPELLANT UNDER PRESSURE
CLAUDE I. MERRILL and JO ANNE ASKINS (New Mexico Inst. of Mining and Technology, Socorro.) *In* AGARD, Insensitive Munitions 13 p (SEE N92-33240 23-28) Jul. 1992
(AGARD-CP-511) Copyright Avail: CASI HC A03/MF A03

Since the Pershing booster motor incident occurred in 1985, much has been learned about how to test for electrostatic discharge (ESD) characteristics and what factors influence ESD initiation sensitivity for solid propellants. Small propellant samples have shown enhanced ESD sensitivity when placed under pressure. Since changes in bulk solid propellant ESD traits under the influence of elevated pressures were not found in our literature surveys, equipment was fabricated so that pressure effects on ESD behavior of a hydroxy terminated polybutadiene (HTPB) propellant could be observed. In addition, a limited additive study was conducted to see if large ion salts could reduce the ESD initiation sensitivity of a sensitive HTPB propellant. Author

N92-33243# Defence Research Establishment Valcartier, Valcartier, Quebec (Canada).
DEVELOPMENT OF A MINIMUM SMOKE PROPELLANT BASED ON GLYCIDYL AZIDE POLYMER AND AMMONIUM NITRATE
P. LESSARD, L. DRUET, S. VILLENEUVE, S. THIBOUTOT, M. BENCHABANE (Bristol Aerospace Ltd., Winnipeg, Manitoba), and D. ALEXANDER (Bristol Aerospace Ltd., Winnipeg, Manitoba) *In* AGARD, Insensitive Munitions 6 p (SEE N92-33240 23-28) Jul. 1992
(AGARD-CP-511) Copyright Avail: CASI HC A02/MF A03

Composite rocket propellants traditionally developed and produced in Canada are based primarily on ammonium perchlorate (AP) dispersed in a polybutadiene (HTPB) binder. Depending on the atmospheric conditions, such propellants can produce a significant amount of secondary smoke which is undesirable for certain applications. To overcome this problem, the Defence Research Establishment, Valcartier (DREV), has initiated the development of a minimum smoke, low vulnerability propellant. The new propellant uses ammonium nitrate (AN) as the oxidizer and glycidyl azide polymer (GAP) as the energetic binder. The efforts made and the characteristics of a baseline minimum smoke formulation are described. This formulation meets minimum criteria for processing safety, chemical stability, and mechanical integrity. It falls short of the performance of an AP/HTPB propellant. Means of improving the performance are described. Author

N92-33244# Royal Ordnance PLC, Kidderminster (England). Rocket Motors Div.
THE DESIGN FEATURES OF ROCKET MOTORS RELATING TO INSENSITIVE MUNITION RESPONSE TO THERMO-MECHANICAL STIMULI
A. C. MASON *In* AGARD, Insensitive Munitions 18 p (SEE N92-33240 23-28) Jul. 1992
(AGARD-CP-511) Copyright Avail: CASI HC A03/MF A03

Since the late 1970's, the Royal Ordnance Rocket Motors Division has conducted insensitive munitions trials on approximately 500 solid propellant rocket motors and data from over 400 of these have been included in a recently structured database. These trials preceded the current standards of MIL-STD-2105 and OB Proc 42657, and as a result, most of these trials were conducted on an individual bases in order to understand the basic responses to a wide range of threats. Although the trials were not undertaken as a balanced series of experiments, analysis of the data does permit some useful observation and comparisons to be made. In particular, the results of the 0.5 inch bullet impact trials and fuel fire (Fast Cook-off) tests were considered to be particularly relevant to the current UK, NATO, and USA requirements and these are discussed in detail. The general conclusions from these trials emphasize the importance of both the propellant type and body structure in the response to either mechanical or thermal attack. The database has enabled the capability of designing solid propellant rocket motors to meet bullet impact and fuel fire requirements. Author

N93-17612# Centre de Recherches du Bouchet, Vert de Petit (France). SNPE, Defense/Espace.
SEMI-PROPELLANTS FOR DUCTED ROCKETS [SEMI-PROPERGOLS POUR STATOFUSEE]
B MAHE, C. PERUT, C. VIGOT (Centre d'Etudes et de Recherches, Toulon, France), and C. MASSON (Centre d'Etudes et de Recherches, Toulon, France) *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 17 p (SEE N93-17607 05-20) Sep. 1992 In FRENCH
(AGARD-CP-526) Copyright Avail: CASI HC A03/MF A03

The purpose of this paper is to describe the different families of fuel-rich solid propellants studied and developed at SNPE and ONERA for ducted rocket applications. These propellants are adjusted for choked gas generator or for unchoked gas generator configurations. They are ordered in three classes depending on their optical signature characteristics and their energetic performance: (1) smokeless propellants without metal; (2) reduced smoke compositions with a low rate of metals for a 'rustique' ducted rocket; and (3) high energy propellants with a high rate of particles--magnesium, carbon, and boron. Major properties of various fuel-rich solid propellants of each family are described. Author

N94-29259# Pratt and Whitney Aircraft, West Palm Beach, FL. Fuels and Lubricants Group.
HIGH TEMPERATURE FUEL REQUIREMENTS AND PAYOFFS
TEDD B. BIDDLE and BENNETT M. CROSWELL *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 12 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by AFWAL and Naval Air Propulsion Test Center
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

This paper describes a study performed under contract to Air Force Wright Laboratory, Wright-Patterson Air Force Base, Dayton, OH in association with the Naval Air Propulsion Laboratory, Trenton, NJ. The study projected fuel temperature capability requirements for future tactical fighter applications and the payoffs that would be realized by achieving these capabilities. The study was approached on the basis of the maximum benefit that might be realized through the use of high temperature fuels, i.e. elimination of the recirculation system. Heat loads were projected for different missions spanning IHPTET technology phases 1, 2, and 3 at different flight conditions. Fuel temperatures across fuel system components were calculated at these heat loads. Shortfalls of the current 163 C fuel capability were shown, and minimun fuel temperature requirements were defined. The study concluded that elimination of the recirculation system is not feasible but shows how high temperature fuel capability can minimize the weight penalty associated with fuel recirculation. In this way, potential payoffs for high temperature fuel development were shown in the form of reduced weight penalties that would normally be encountered as larger and larger recirculation systems are required to accommodate the increasing heat loads projected for advanced aircraft. Author (revised)

N94-29260# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain). Fuels and Lubricants Lab.
HIGH TEMPERATURE RESISTANT JET FUELS
LUIS M. PELOCHE and SANTIAGO ASENSIO *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 9 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by British Petroleum Oil, Inc.
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

The thermal stability of aviation fuels is evaluated according to the ASTM D 2341 method. This characteristic is linked to the presence of generators of instability, mainly diolephins and N and S derivates. The objectives of the present work are as follows: to obtain, in the laboratory, kerosene which is thermally stable; the isolation and identification of generators of instability; and the regeneration of thermally unstable kerosenes. Author (revised)

N94-29261# Wright Lab., Wright-Patterson AFB, OH.
RESEARCH AND DEVELOPMENT OF HIGH THERMAL STABILITY FUELS
T. EDWARDS, W. M. ROQUEMORE, W. E. HARRISON, and S. D. ANDERSON *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 19 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

Increases in aircraft performance are leading to increases in the thermal stress on the primary aircraft coolant--the fuel. Fuel thermal stability limitations may offset future aircraft performance gains. The Air Force's Wright Laboratory is sponsoring several research programs to address this problem. The development of an additive package for JP-8 to improve its thermal stability is the primary focus of this paper. This program involves extensive testing of fuels and additives in a variety of test devices, culminating in tests in a fuel system simulator and engine tests. These tests involve Air Force personnel, on-site contractors (University of Dayton Research Institute, Systems Research Laboratories), Pratt and Whitney Aircraft Co., additive manufacturers, and Sandia National Laboratory. The test devices include several flowing and static tests, where the behavior of a fuel is investigated in a wide variety of environments. The study of several baseline fuels in these devices has led to some new insights into the mechanisms of fuel thermal (in)stability. It is becoming clear that a fuel's tendency to oxidize (to form peroxides, for example) is often inversely proportional to its tendency to form insoluble deposits. Author (revised)

N94-29262# Systems Research Labs., Inc., Dayton, OH.
DEVELOPMENT OF GLOBAL/CHEMISTRY MODEL FOR JET-FUEL THERMAL STABILITY BASED ON OBSERVATIONS FROM STATIC AND FLOWING EXPERIMENTS
V. R. KATTA, E. G. JONES, and W. M. ROQUEMORE *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 11 p (SEE N94-29246 08-25) Sep. 1993
(Contract(s)/Grant(s): F33615-90-C-2033)
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

Two global-chemistry models for oxidative deposition of jet fuels are evaluated by integrating them into a Computational Fluid Dynamics with Chemistry (CFDC) code. A previously developed two-step global-chemistry model was found to be insufficient to describe the thermal-oxidation and -deposition rates associated with a Jet-A fuel. A new global-chemistry model has been developed systematically based on observations from flowing and static experiments. The global-autoxidation reaction is modified such that the reaction rate becomes zeroth-order with respect to the dissolved oxygen concentration. The generation of deposit-forming precursor is coupled with the autoxidation reaction by introducing a radical species ROO. A formulation for the sticking probability has also been developed. Deposition profiles are well represented by this new model under a variety of temperature and flow conditions. The model correctly predicts the changes in magnitude and spatial location of the deposition peak due to changes in flow. The CFDC model, which is designed for flowing systems, has been extended to static experiments. The model incorporates a non-depleting species F(sub s) representing all non-oxygen compounds responsible for deposition. Static experiments were found to provide a useful and inexpensive method for estimating the concentration of F(sub s) in the fuel. Author

N94-29285# Central Inst. of Aviation Motors, Moscow (Russia).
ENDOTHERMIC FUELS FOR HYPERSONIC AVIATION
LEONID S. IANOVSKI and CLIFFORD MOSES *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 8 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A02/MF A04

The creation of hypersonic vehicles and the use of jet engines with higher temperature cycles has resulted in a significant increase in the thermal stresses of the engine elements. In order to use the fuel as the coolant for these elements, it is necessary to increase the heat capacity of hydrocarbon fuels. This problem can be solved by taking advantage of such high temperature chemical processes as catalytic dehydrogenation and thermal cracking or pyrolysis of hydrocarbon fuels, including the addition of the initiators and catalysts. The chemical heat capacity of hydrocarbon fuels can be used for the direct cooling of such elements as combustion chambers, nozzles, and front wing edges; indirect cooling of these elements can be accomplished by using a heat-transport medium in the fuel/air or fuel/gas heat exchangers. The gaseous products of the decomposed fuels can be used as a working medium for the drive of the equipment of a fuel/feeding system. Author (revised)

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MATERIALS PROCESSING

Includes space-based development of products and processes for commercial applications.

N92-28450*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION FREEDOM MICROGRAVITY ENVIRONMENT REQUIREMENTS AND ASSESSMENT METHODS
PHILIP BOGERT *In* NASA. Lewis Research Center, International Workshop on Vibration Isolation Technology for Microgravity Science Applications p 321-344 (SEE N92-28436 19-31) May 1992
(AGARD-AG-329) Avail: CASI HC A03/MF A04

An overview of the Space Station Freedom's microgravity requirements is provided in viewgraph form. Additionally, the following topics are covered: (1) quasi-steady assessment

techniques; (2) low frequency vibration assessment techniques; and (3) vibroacoustic assessment techniques. Author

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ENGINEERING (GENERAL)

Includes vacuum technology; control engineering; display engineering; cryogenics; and fire prevention.

N93-22018# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
ADVANCES IN GUIDANCE AND CONTROL OF PRECISION GUIDED WEAPONS [LES AVANCEES DANS LE DOMAINE DU GUIDAGE ET DU PILOTAGE DES ARMES GUIDEES DE PRECISION]
Nov. 1992 122 p 54th Symposium held in Ottawa, Canada, 12-14 May 1992
(AGARD-CP-524; ISBN-92-835-0692-8) Copyright Avail: CASI HC A06/MF A02
This volume contains the Technical Evaluation Report and the 12 unclassified papers, presented at the Guidance and Control Panel Symposium held in Ottawa, Canada from 12th-14th may 1992. The papers were presented covering the following headings: (1) Desert Storm Experience; (2) Advanced Sensors; (3) Guidance and Control Techniques; (4) System Concepts and Assessments; and (5) Standoff Weapons and Technology. For individual titles, see N93-22019 through N93-22030.

N93-22027# Naval Air Warfare Center, China Lake, CA. Attack Weapons Dept.
VERSATILE ATTACK WEAPON
D. QUIST *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 4 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A01/MF A02
The air defense threat to air strike forces continues to increase, both in quality and quantity. Third World countries now possess Integrated Air Defense (AID) capabilities equaling that of major powers. Radio Frequency (RF) only Anti-Radiation Homing (ARH) weapons are being effectively neutralized by countermeasure improvements in these land based and satellite IAD systems. The cost of piecemeal modification of existing weapon systems or the continuous fielding of threat specific weapon systems is becoming prohibitive. A low funded in-house project was started in 1988 that confronts this defense threat situation with a multi-mode multi-mission weapon system which is affordable to employ in large quantities. The system has capabilities as both a defense suppression weapon and a surgical strike weapon. Employment can be facilitated from a reduced threat environment to air strike forces. Other objectives for this innovative weapon system are the capabilities for high target damage, countermeasure resistance, real time aim point selection, and real time Battle Damage Assessment (BDA). Technical feasibility of the various system and subsystem elements were verified by theoretical analysis. Many were also verified by physical demonstration in prototype hardware. Author (revised)

N93-22029# Alenia Aeronautica, Turin (Italy). Defense Aircraft Div.
SYSTEM CONCEPT FOR AN ADVANCED STAND-OFF WEAPON
RICCARDO BARZAN *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 8 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A02/MF A02
A typical conceptual design process is described as applicable to an advanced Stand Off Weapon (SOW). Different design requirement sets, which include system performance parameters, are established to satisfy different mission requirements. In order to cope with these sets and to reach the flexibility needed, some specific design criteria are suggested. The trade between modularity and commonality makes the difference among different SOW's and affects them in affordability and effectiveness. The Skyshark weapon system is given as example of an SOW system concept. The description allows the understanding of links between design requirements, design criteria, and technical characteristics. Extensive modularity is adopted for all components that enhance flexibility (Armament, Avionics, Propulsion), while a favorable configuration layout choice allows maximizing commonality. This paper presents an industrial point of view and is related to almost 10 years of Alenia activities on Stand Off Weapons.
Author (revised)

N94-10613# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
ENVIRONMENTALLY SAFE AND EFFECTIVE PROCESSES FOR PAINT REMOVAL [LES PROCEDES EFFICACES ET ECOLOGIQUES POUR L'ENLEVEMENT DES PEINTURES]
Mar. 1993 133 p The 75th meeting was held in Lindau, Germany, 7-8 Oct. 1992
(AGARD-R-791; ISBN-92-835-0705-3; AD-A267003) Copyright Avail: CASI HC A07/MF A02
Paint stripping and repainting of aircraft surfaces are required periodically during the operating lifetime of an aircraft. Historically, paint removal has been achieved with chemical strippers. These materials often contain toxic components and create hazardous working conditions. It is necessary to ensure that alternate paint removal techniques are available that can be performed in a cost effective, environmentally safe manner without causing damage to aircraft surfaces. For individual titles, see N94-10614 through N94-10629.

N94-10614# Naval Air Warfare Center, Warminster, PA. Aircraft Div.
PAINT REMOVAL ACTIVITIES IN THE US NAVY
JOSEPH KOZOL *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 5 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A01/MF A02
Use of methylene chloride and phenol based chemical strippers for aircraft paint removal generates large quantities of hazardous waste and creates health and safety problems for operating personnel. This paper presents an overview of the U.S. Navy's activities in the investigation and implementation of alternate paint stripping methods which will minimize or eliminate hazardous waste and provide a safe operating environment. Alternate paint removal methods under investigation by the Navy at the present time include use of non-hazardous chemical paint removers, xenon flashlamp/CO2 pellets, lasers and plastic media. Plastic media blasting represents a mature technology in current usage for aircraft paint stripping and is being investigated for determination of its effects on Navy composite aircraft configurations.
Author (revised)

N94-10615# Defence Research Establishment Pacific, Victoria (British Columbia).
PAINT REMOVAL ACTIVITIES IN CANADA
TERRY FOSTER *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 3 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A01/MF A02
Paint removal activities currently under way in Canada include: research and development of laser paint stripping; development and commercialization of a new blasting medium based on wheat starch; commercialization of a new blasting medium and process using crystalline ice blasting for paint removal and surface cleaning; and the development of automated and robotic systems for paint stripping applications. A specification for plastic media blasting (PMB) of aircraft and aircraft components is currently being drafted by NDHQ for use by the Canadian Armed Forces (CAF) and contractors involved in coating removal for the CAF. Defense Research Establishment Pacific (DREP) is studying the effects of various blast media on coating removal rates, and minimizing the possibility of damage to substrates other than aluminum such as graphite epoxy composite and Kevlar. The effects of plastic media blasting on liquid penetrant detection of fatigue cracks is also under investigation. Author (revised)

N94-10616# Delegation Generale de l'Armement, Toulouse (France).
PROCEDURES WITHOUT DANGER TO THE ENVIRONMENT AND EFFICIENCY (PSDEE) FOR THE REMOVAL OF PAINT. POINT ON THE FRENCH ACTIVITIES CONCERNING THE REMOVAL OF PAINT [PROCEDES SANS DANGER POUR L'ENVIRONNEMENT ET EFFICACES (PSDEE) POUR L'ENLEVEMENT DES PEINTURES. POINT SUR LES ACTIVITIES FRANCAISES CONCERNANT L'ENLEVEMENT DES PEINTURES]
PIERRE GAUTHIER *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 6 p (SEE N94-10613 01-31) Mar. 1993 In ENGLISH and FRENCH
(AGARD-R-791) Copyright Avail: CASI HC A02/MF A02
The text presents a synthesis of the activities and subjects of French interest in new techniques for the removal of paint in the civil and military air transport sector. Transl. by FLS

N94-10617# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany).
PAINT REMOVAL ACTIVITIES IN GERMANY
R. HOLBEIN and G. ARNOLDS-MAYER *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 5 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A01/MF A02
To replace paint removing chemicals containing chlorinated hydrocarbons several alternative paint stripping methods have been developed or are under study in Germany: high pressure water stripping; plastic media blasting; use of alcalic and acid activated softeners; CO2 pellet blasting; and laser application. Author (revised)

N94-10618# Royal Air Force, Harrogate (England). Surface Finish Support Authority.
THE DEVELOPMENT OF ALTERNATIVE PAINT REMOVAL TECHNIQUES IN THE RAF
M. HARTLEY and M. WEEDING *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 8 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A02/MF A02
Personnel safety and environmental legislation is forcing the removal of chemical removers. The RAF chose the Plastic Media Stripping process as their alternative. During testing of the process a number of problem areas and additional advantages were highlighted. Solution to the problems are discussed and the advantages quantified. Author (revised)

N94-10619# Fokker B.V., Amsterdam (Netherlands).
OPERATIONAL ASPECTS OF F.16 PLASTIC MEDIA BLASTING, AS CARRIED OUT BY FOKKER AIRCRAFT SERVICES
FRANK POT *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 3 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A01/MF A02
In 1987, Fokker Aircraft Services started F.16 air-intake paint removal by means of Plastic Media Blasting (PMB). Especially for this process, a robot has been developed. In a later stage, complete exterior PMB-paint removal has been tested and successfully adopted. The paint removal is carried out in the scope of a thorough corrosion control program. The requirement that all the paint must be removed in order to allow this control program to be carried out properly, leads to severe masking complications. The process parameters are relatively conservative, because of the requirement that absolutely no anodic layer damage is permitted. Following PMB paint removal, corrosion is removed using aluminum oxide blasting. Finally, a highly flexible polyurethane paint system is applied, based upon TT-P-2760 Koroflex primer. To summarize the process, it can be stated that the plastic media blasting itself is straightforward. Proper masking is difficult to perform though, compounded by special customer requirements such as open panel edges. Author (revised)

N94-10620# Aerospatiale, Toulouse (France).
USE OF ROBOTS FOR AIRCRAFT DRY STRIPPING VIA PLASTIC MEDIA BLASTING
E. GILLARD *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 6 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A02/MF A02
In order to meet constant financial and reliability concerns, European manufacturers have introduced more and more composite materials on their aircraft. In addition to fairings for which the use of composites has become absolutely necessary, composites are used on each new program for structures which are more and more highly loaded and sophisticated. Similarly to metallic structures, an external paint scheme is applied to these composite structures to protect them from ultraviolet rays, provide general corrosion resistance and allow the airlines to customize their aircraft. Conventional stripping methods using chemical strippers cannot be used as many impregnation resins do not resist chemical strippers. Aerospatiale has endeavored to find new efficient methods that are easy to implement, cause no damage and are applicable both to metallic and composite structures. Dry stripping via plastic media blasting has formed the subject of many tests. These tests proved that such stripping was compatible with the objectives but required automation of the process for large airframe stripping. Author

N94-10621# German Air Force, Cologne (Germany). Support Command.
GERMAN AIR FORCES EXPERIENCES WITH PLASTIC MEDIA BLASTING AND FUTURE REQUIREMENTS
MATTHIAS STOERMER *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 14 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A03/MF A02
German Air Force (GAF) has been researching a method of paint removal for a couple of years to replace the chemical method still in use. This is to improve corrosion prevention, environmental protection and health care. With the support of German aerospace company MBB and the University of the Armed Forces in Munich GAF selected Plastic Media Blasting (PMB) as the most suitable method. Having a stripping facility for the entire aircraft at MBB Manching already in existence, GAF decided that the next step forward to gain more experiences is to establish a smaller 'stripping cabin' at an air force base. This cabin is suitable for stripping removable parts and components of aircraft and equipment with the max. size of a half dismantled TORNADO wing. With these gained experiences GAF will be in position to formulate the specific requirements for an entire on-base aircraft stripping plant which will be suitable for F-4's, TORNADO's and EFA's, too. Author (revised)

N94-10622# Air Force Logistics Command, Hill AFB, UT.
PLASTIC MEDIA BLASTING ACTIVITIES AT HILL AIR FORCE BASE
J. D. CHRISTENSEN *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 2 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A01/MF A02
Hill Air Force Base in Utah developed plastic media blasting (PMB) paint removal process for removing paint from Air Force aircraft. The development of the process involved extensive testing of various abrasives and subsequent parameters to end up with an approved production process. Hill AFB has been using PMB in a production mode since 1985, and completely discontinued chemical stripping of airframes in 1989. We have recently installed and began operating a fully automated PMB facility that utilizes two nine-axis robots to strip an aircraft. This system has enabled us to further reduce the manhours required to strip an aircraft, and also allowed us to remove the employee from the blasting atmosphere into a control room. We have, and will continue to realize, significant environmental and economic savings by using PMB. Hill is also actively involved with the development of future paint stripping technologies. Derived from text

N94-10623# Wright Lab., Eglin AFB, FL. Manufacturing Technology Directorate.

LARGE AIRCRAFT ROBOTIC PAINT STRIPPING (LARPS) SYSTEM AND THE HIGH PRESSURE WATER PROCESS

DAVID W. SEE, SCOTT A. HOFACKER (United Technologies Corp., Huntsville, AL.), M. ANTHONY STONE (United Technologies Corp., Huntsville, AL.), and DARCY HARBAUGH (United Technologies Corp., Huntsville, AL.) *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 21 p (SEE N94-10613 01-31) Mar. 1993

(Contract(s)/Grant(s): F33615-91-C-5708)

(AGARD-R-791) Copyright Avail: CASI HC A03/MF A02

The aircraft maintenance industry is beset by new Environmental Protection Agency (EPA) guidelines on air emissions, Occupational Safety and Health Administration (OSHA) standards, dwindling labor markets, Federal Aviation Administration (FAA) safety guidelines, and increased operating costs. In light of these factors, the USAF's Wright Laboratory Manufacturing Technology Directorate and the Aircraft Division of the Oklahoma City Air Logistics Center initiated a MANTECH/REPTECH effort to automate an alternate paint removal method and eliminate the current manual methylene chloride chemical stripping methods. This paper presents some of the background and history of the LARPS program, describes the LARPS system, documents the projected operational flow, quantifies some of the projected system benefits and describes the High Pressure Water Stripping Process. Certification of an alternative paint removal method to replace the current chemical process is being performed in two phases: Process Optimization and Process Validation. This paper also presents the results of the Process Optimization for metal substrates. Data on the coating removal rate, residual stresses, surface roughness, preliminary process envelopes, and technical plans for process Validation Testing will be discussed. Author (revised)

N94-10624# International Technical Associates, Inc., Santa Clara, CA.

AUTOMATED LASER PAINT STRIPPING (ALPS) UPDATE

PAUL LOVOI *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 12 p (SEE N94-10613 01-31) Mar. 1993

(AGARD-R-791) Copyright Avail: CASI HC A03/MF A02

To date, the DoD has played a major role in funding a number of paint stripping programs. Some technologies have proven less effective than contemplated. Others are still in the validation phase. Paint stripping is one of the hottest issues being addressed by the finishing industry since the Environmental Protection Agency (EPA) has mandated that chemical stripping using methylene chloride/phenolic type strippers be stopped. The DoD and commercial aircraft companies are hard-pressed to find an alternative. Automated laser paint stripping has been identified as a technique for removing coatings from aircraft surfaces. International Technical Associates (InTA) was awarded a Navy contract for an automated laser paint stripping system (ALPS) that will remove paint from metallic and composite substrates. For the program, which will validate laser paint stripping, InTA will design, build, test, and install a system for fighter-sized aircraft at both the Norfolk and North Island (San Diego) Aviation Depots. Derived from text

N94-10625# Deutsche Lufthansa A.G., Hamburg (Germany). Structural Engineering Dept.

AQUASTRIP (TM): AN INNOVATIVE PAINT REMOVAL TECHNOLOGY

J. VOLKMAR *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 10 p (SEE N94-10613 01-31) Mar. 1993

(AGARD-R-791) Copyright Avail: CASI HC A02/MF A02

Environmental, safety and health issues, forced operators to search for an alternative paint removal process. High pressure water jetting and new integrated paint and stripper systems are Lufthansa's answer to this challenge. AQUASTRIP complies with the specification requirements. In order to receive approval from airframe manufacturers and authorities the process has undergone an extensive research program since 1988. An operation window was established, to enable maximum of safety during operation on metal and composite surfaces. Even though AQUASTRIP is a hybrid process and requires technological investment, it is well on the way to prove its innovative, ecological and economical character in first large scale applications under realistic conditions. Its potential has already been reflected by patents and trademarks, which were registered in conjunction with the development of AQUASTRIP and the vital interest for cooperative work on the process development and other potential utilization. Author (revised)

N94-10626# Defence Research Establishment Pacific, Victoria (British Columbia).

PAINT REMOVAL AND SURFACE CLEANING USING ICE PARTICLES

TERRY FOSTER and S. VISAISOUK (Ice Blast International Corp., Victoria, British Columbia.) *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 10 p (SEE N94-10613 01-31) Mar. 1993

(AGARD-R-791) Copyright Avail: CASI HC A02/MF A02

Research into the possibility of using ice particles as a blast medium was first initiated at Defence Research Establishment Pacific (DREP) in an effort to develop a more environmentally acceptable paint removal method. A paint removal process was also required that could be used in areas where normal grit blasting could not be used due to the possibility of the residual blasting grit contaminating machinery and other equipment. As a result of this research a commercial ice blasting system was developed by RETECH. This system is now being used to remove paint from substrates that cannot be easily blasted by conventional techniques and also to clean soiled or contaminated surfaces. The problems involved in the development of an ice blast system, and its components and their functions are described. Due to the complexity of paint removal using ice blasting, parameters such as air pressure, ice particle size and ice particle flow rate were studied and adjusted to suit the nature of the particular coating and substrate of interest. The mechanism of paint removal by ice particles has also been investigated. A theoretical model has been developed to explain the different paint removal mechanisms such as erosion by abrasion and erosion by fracture as they relate to ice blasting. Finally, the use of ice blasting to removal paint from a variety of substrates is presented as well as examples of surface cleaning and surface decontamination. Author

N94-10627# Defence Research Establishment Pacific, Victoria (British Columbia).

PAINT REMOVAL USING WHEAT STARCH BLAST MEDIA

TERRY FOSTER and JOHN OESTREICH (Ogilvie Mills Ltd., Montreal, Quebec.) *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 9 p (SEE N94-10613 01-31) Mar. 1993

(AGARD-R-791) Copyright Avail: CASI HC A02/MF A02

A review of the Wheat Starch Blasting technology is presented. Laboratory evaluations covering Almen Arc testing on bare 2024-T3 aluminum and magnesium, as well as crack detection on 7075-T6 bare aluminum, are discussed. Comparisons with Type V plastic media show lower residual stresses are achieved on aluminum and magnesium with wheat starch media. Dry blasting effects on the detection of cracks confirms better crack visibility with wheat starch media versus Type V or Type II plastic media. Testing of wheat starch media in several composite test programs, including fiberglass, Kevlar, and graphite-epoxy composites, showed no fiber damage. Process developments and production experience at the first U.S. aircraft stripping facility are also reviewed. Corporate and regional aircraft are being stripped in this three nozzle dry blast hangar. Author

N94-10628# KLM Aerocarto, Schiphol (Netherlands). Central Engineering Dept.

IATA TASKFORCE: PAINTSTRIPPING

THOMAS MOOY *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 5 p (SEE N94-10613 01-31) Mar. 1993

(AGARD-R-791) Copyright Avail: CASI HC A01/MF A02

In 1990 the International Air Transport Association (IATA) established a task force to stimulate the development of alternatives for chemical stripping of commercial aircraft. The IATA TaskForce Paintstripping objectives are: to identify the most promising, current alternatives for short term implementation; to prepare a document containing requirements for the development of alternatives; to stimulate the information exchange. After the September 1992 meeting the TaskForce will report back to IATA.

The most tangible result of the TaskForce is the IATA Guidelines containing requirements for the qualification of stripping processes. Author (revised)

N94-10629# Imperial Chemical Industries Ltd., Duesseldorf (Germany). Aerospace Coatings.
SELECTIVELY STRIPPABLE PAINT SCHEMES
R. STEIN, D. THUMM, and ROGER W. BLACKFORD (Imperial Chemical Industries Ltd., Slough, England.) *In* AGARD, Environmentally Safe and Effective Processes for Paint Removal 4 p (SEE N94-10613 01-31) Mar. 1993
(AGARD-R-791) Copyright Avail: CASI HC A01/MF A02

In order to meet the requirements of more environmentally acceptable paint stripping processes many different removal methods are under evaluation. These new processes can be divided into mechanical and chemical methods. ICI has developed a paint scheme with intermediate coat and fluid resistant polyurethane topcoat which can be stripped chemically in a short period of time with methylene chloride free and phenol free paint strippers. Author

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COMMUNICATIONS AND RADAR

Includes radar; land and global communications; communications theory; and optical communications.

N92-22792*# Johns Hopkins Univ., Laurel, MD. Applied Physics Lab.
SENSING PROPAGATION EVENTS AND FADE STATISTICS AT C-BAND FOR TWO OVER-WATER, LINE-OF-SIGHT PROPAGATION PATHS OVER A ONE YEAR PERIOD
JULIUS GOLDHIRSH, G. DANIEL DOCKERY, and BERT H. MUSIANI *In* AGARD, Remote Sensing of the Propagation Environment 12 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by NASA. Wallops Flight Facility
(Contract(s)/Grant(s): N00039-89-C-0001)
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

We examine signal fading statistics over a year period corresponding to two over-water, line-of-site, propagation links in the mid-Atlantic coast of the US. These links are comprised of a transmitter on a tower at Parramore Island, VA operating at 4.7 GHz sending simultaneous cw signals to two receiver systems located on a lighthouse and a lookout tower on Assateague Beach, VA at distances of 44 and 39 km, respectively. The receiving sites are separated by approximately 5 km. Cumulative fade distributions corresponding to yearly, monthly, and diurnal time scales were derived. Fade duration statistics correspond to sustained attenuation events were also derived. These events, which were arbitrarily defined as having fades relative to free space powers in excess of 20 dB for durations of two hours or more, are believed to be generally due to subrefraction. Analysis of synoptic weather conditions and nearby rawindsonde data during two sustained deep fading periods showed atmospheric conditions consistent with extreme subrefraction, where the refractivity-height profile had a positive lapse rate. The efficacy of employing the links as indicators of real time conditions of atmospheric propagation was also demonstrated by a telephone call-up procedure which enabled displays of time series of the fading at remote locations to be generated. Author

N92-22794# Centre d'Electronique de l'Armement, Bruz (France). Div. ASRE.
OVER THE HORIZON PROPAGATION IN A MARINE ENVIRONMENT: MODELLING AND RECENT EXPERIMENTAL RESULTS
JACQUES CLAVERIE and YVONICK HURTAUD *In* AGARD, Remote Sensing of the Propagation Environment 14 p (SEE N92-22790 13-46) Feb. 1992 In FRENCH
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

In the context of work undertaken by the Propagation subgroup AC 243/RSG8/com. III, two important series of measurements were taken in the neighborhood of the French coast: in the Atlantic (Lorient region) in the Fall of 1989, and in the Mediterranean (Toulon region) during the summer of 1990. These were measurements of over-the-horizon links above the sea, at a sweeping angle, with wavelengths in centimeters and millimeters (from 3 to 94 GHz). In order to precisely characterize the limit layer of the oceanic surface, meteorological measurements were undertaken using automatic stations on buoys placed near the line of sight and radiosondes suspended from balloons. The data set gathered enables the completion and validation of a program for global calculation of propagation in a marine environment. This program is constructed from a propagation model, based on the parabolic equation method and from an environment model developed based on a 'bulk' type procedure. Statistical analysis of the experimental data demonstrates the good quality of the combination of models used. The advantage of a multifrequency approach is also clearly shown. However, the temporal comparison between predicted and measured propagation losses proves to be more complex. An appreciable improvement can be made by taking into account the level of measurements taken and environmental models, complex atmospheric situations, and spatial discrepancies. Transl. by L.B.

N92-22795# Centre d'Etudes et de Recherches, Toulouse (France). Departement Micro-Ondes.
A THEORETICAL STUDY OF A RADIOWAVE CHARACTERIZATION METHOD OF THE EVAPORATION DUCT
N. DOUCHIN (Centre National d'Etudes Spatiales, Toulouse (France).), S. BOLIOLI (Centre National d'Etudes Spatiales, Toulouse (France).), F. CHRISTOPHE (Centre National d'Etudes Spatiales, Toulouse (France).), and P. COMBES (Toulouse Univ., France) *In* AGARD, Remote Sensing of the Propagation Environment 15 p (SEE N92-22790 13-46) Feb. 1992 In FRENCH; ENGLISH summary
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

The aim in this study is to consider the possibility of identifying the evaporation duct parameters from a fluctuation analysis of a near the horizon satellite-ship path. The latter is split in two different parts and reciprocity is applied. Thus, we get two different field distributions on a connecting interface which has to be suitable for a good calculation of the coupling between both of them. Then, the model is used with the intention of evaluating the fluctuations of the received signal due to the movement of the satellite and their sensitivity to the parameters of the propagation medium: sea roughness, height, and strength of the evaporation duct; and presence of horizontal gradients in the refractive index distribution. Obviously, sensitivity to these parameters is examined for several values of the frequency. Author

N92-22796# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
RADIO REFRACTIVITY PROFILES DEDUCED FROM AEROSOL LIDAR MEASUREMENTS
H. G. HUGHES, M. R. PAULSON, and J. H. RICHTER *In* AGARD, Remote Sensing of the Propagation Environment 6 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Office of Naval Technology
(AGARD-CP-502; AD-A249074) Copyright Avail: CASI HC A02/MF A03

A technique is presented for estimating radio wave ducting conditions from shipboard curing cloud-free periods using a lidar system to measure the power from a pulsed laser beam that is backscattered to a receiver from suspended particulates (aerosols) at different ranges. On individual days, the relative humidity measured with altitude using radiosondes launched simultaneously with vertical lidar shots, were highly correlated with the range-compensated power received by the lidar from the same altitude. However, the relationship between the power returns and the relative humidities changed from day to day, indicating an air mass characteristic dependence on the aerosols' optical parameters. Using a combined data set of 13 days, a linear relationship (correlation = 0.73) was determined between the relative humidity at a given altitude and the range-compensated power received by the lidar from the same altitude. While the magnitudes differed in most cases, the gradients in modified radio refractivity calculated using standard vertical lapse rates of temperature and pressure with the experimentally determined relationship were in close agreement with those calculated using the radiosonde measured parameters. Examples of radio signal coverage plots based on the lidar returns are presented and

compared with those calculated from the radiosonde data for both elevated and ground-based ducting conditions. Author

N92-22797# Rutherford Appleton Lab., Chilton (England). Radio Communications Research Unit.

USE OF MESOSCALE MODELS FOR REFRACTIVITY FORECASTING

M. F. LEVY and K. H. CRAIG *In* AGARD, Remote Sensing of the Propagation Environment 12 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Ministry of Defence

(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

Three-dimensional forecasts of sensor performance require accurate predictions of refractivity features. Numerical weather models like the UK mesoscale model have become sufficiently powerful to provide good refractivity maps. These in turn provide environmental input for parabolic equation models to forecast microwave propagation. The UK mesoscale model and its application to forecasting sensor performance are briefly described. Author

N92-22798# Pacific Missile Test Center, Point Mugu, CA.

REFRACTIVE ASSESSMENTS FROM SATELLITE OBSERVATIONS

JAY ROSENTHAL and ROGER HELVEY *In* AGARD, Remote Sensing of the Propagation Environment 9 p (SEE N92-22790 13-46) Feb. 1992

(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Capabilities of estimating ducting conditions for certain ocean regions (and weather regimes) from meteorological satellite data are under development at the Pacific Missile Test Center, in support of the Navy's Electromagnetic Propagation Assessment and Tactical Environmental Support System (TESS) program offices. Visual imagery patterns are used to infer the occurrence, height, and intensity of ducts, while processed infrared (IR) and visual imagery are used to infer the spatial distribution of duct heights. Special cloud signature techniques were developed on a personal computer to help correct for contamination of cloud-top temperatures due to sea and cloud anomaly features which impact the IR-duct technique. Synoptic, mesoscale, and geographical influences on the propagation environment are considered as part of the effort to develop a predictive capability. Author

N92-22814# Atmospheric Sciences Lab., White Sands Missile Range, NM.

FAR-INFRARED CHARACTERIZATION OF HORIZONTAL PATH IMAGE DEGRADATION

WENDELL R. WATKINS *In* AGARD, Remote Sensing of the Propagation Environment 11 p (SEE N92-22790 13-46) Feb. 1992

(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

Recent measurements by the Mobile Imaging Spectroscopy Laboratory (MISL) have shed new light on the real degradation produced by atmospheric propagation on far-infrared imaging systems. By the hot and cold bars and the unique measurement technique of closeup and distant simultaneously collected matched imagery of a large area blackbody target board, the atmospheric modulation transfer function (AMTF) was shown to be definitely nonzero for both atmospheric horizontal path turbulence and aerosol clouds. In addition, observations of the target board without the bar pattern and uniform backgrounds were used to compare the MISL measured contrast transmission with LOWTRAN calculations. D.R.D.

N92-22820# Forschungsinstitut der Deutschen Bundespost, Darmstadt (Germany).

DIGITAL CHANNEL SOUNDER FOR REMOTE SENSING OF SCATTERERS IN MOBILE RADIO ENVIRONMENT

RUDOLF WERNER LORENZ and GERHARD KADEL *In* AGARD, Remote Sensing of the Propagation Environment 9 p (SEE N92-22790 13-46) Feb. 1992

(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

A channel sounder called RUSK 400 is described. It is capable of recording complex impulse responses (IRs) in mobile environment. Thanks to digital signal processing, RUSK 400 measures IRs with large dynamic range. RUSK 400 was calibrated to allow for quantitative analysis. Doppler analysis of the measured results can be performed because the data are stored rapidly, and therefore, the sampling theorem can be fulfilled. For determination of delays, the resolution is restricted to about 5 microns because of the small bandwidth of only 400 kHz. The resolution is good enough to perform propagation measurements with the goal of improving of propagation models which use topographical terrain data bases. The determination of angles of arrival is restricted; reasons are given and discussed. The shortcomings of poor resolution and left-right ambiguity can be overcome if it is possible to measure complex IRs at the same location by driving in different directions. RUSK 400 will be used for quantitative determination of magnitudes of waves scattered by terrain slopes. The results will be used to improve automatic field strength prediction methods and estimation of the delay spread caused by mountains. Author

N92-22821# Illinois Univ., Chicago, IL. Communications and Sensing Lab.

BASIC EQUATIONS OF RADAR POLARIMETRY AND SOLUTIONS THE SENSING OF PROPAGATION PATH POLARIZATION STATE CHANGES

WOLFGANG-MARTIN BOERNER (Illinois Univ., Chicago.), WEI-LING YAN (Illinois Univ., Chicago.), AN-QING XI (Illinois Univ., Chicago.), and YOSHIO YAMAGUCHI (Niigata Univ., Japan) *In* AGARD, Remote Sensing of the Propagation Environment 9 p (SEE N92-22790 13-46) Feb. 1992

(Contract(s)/Grant(s): N00014-80-C-0773; N00014-90-J-1405; DAAL03-89-K-0116)

(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Basic principles of radar polarimetry are introduced. The target characteristic polarization state theory is developed first for the coherent case using the three step, the basic transformation, and the power (Mueller) matrix optimization procedures. Kennaugh's and Huynen's theories of radar target polarimetry are verified for the monostatic reciprocal case. It is shown that there exist in total five unique pairs of characteristic polarization states for the symmetric scattering matrix of which the two pairs, the cross polarization null and copolarization max pairs, are identical; whereas, the cross pol max and the cross pol saddle point are distinct. These three pairs of orthogonal characteristic states are also mutually orthogonal on the polarization sphere. The fifth pair, the co-pol null pair lies in the plane spanned by the co-pol max/-cross pol null and the cross pol max pairs which determines the target characteristic circle on the polarization sphere reestablishing Huynen's polarization fork concept. The theory is verified by an example for which next to the polarization fork also the copolarized and cross polarized power density plots are presented. Author

N92-22822# Niigata Univ. (Japan). Faculty of Electronics.

ADAPTIVE COMMUNICATIONS POLARIMETRY: SENSING OF PROPAGATION PATH CHANGES AND ADAPTATION TO OPTIMAL PERFORMANCE IN CELLULAR COMMUNICATIONS

YOSHIO YAMAGUCHI (Niigata Univ. (Japan).), HYO JOON EOM (Korea Inst. of Tech., Tae-Jon (Republic of Korea).), and WOLFGANG-MARTIN BOERNER (Illinois Univ., Chicago.) *In* AGARD, Remote Sensing of the Propagation Environment 6 p (SEE N92-22790 13-46) Feb. 1992

(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Basic principles of radar polarimetry are applied to radio communications under the conditions that the polarization state of the incoming wave changes according to effects caused by the propagation environment. Since the polarization state of an incoming wave cannot be controlled, the only possible way to control the receiving power is the polarization state of the receiving antenna. Based on basic principles of radar polarimetry, the matching and mismatching conditions are derived using the Poincare sphere. An interesting relation was found between the maximal and minimal polarization states with respect to that of the incoming wave, i.e., these points constitute a great circle on the Poincare sphere and that they form a right angle triangle on the great circle. Therefore, if the polarization of the incoming wave is given, these maximal and minimal polarization points can be determined graphically on the Poincare sphere instantaneously. This concept of adaptive communications polarimetry may be useful not only to cellular radio communication systems, but to fixed station link radio communication systems suffering from atmospheric fluctuations as well. Author

N92-22825# Centre National d'Etudes des Telecommunications, Lannion (France).

A CALIBRATION TECHNIQUE FOR THE CNET HF BACKSCATTER RADAR

N. RUELLE (Centre National d'Etudes des Telecommunications, Lannion (France).), F. GAUTHIER (Centre National d'Etudes des Telecommunications, Lannion (France).), J. Y. LESAOUT (Centre National d'Etudes des Telecommunications, Lannion (France).), L. BERTEL (Rennes Univ. (France).), and V. BALTAZART (Rennes Univ., France) *In* AGARD, Remote Sensing of the Propagation Environment 6 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

A calibration procedure is described which is used in conjunction with the CNET HF backscatter radar at Losquet Island, France. This procedure characterizes the capability of the radar to determine angles of arrival of echoes by beam scanning. Author

N92-28084# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.

ADVANCES IN FIBRE-OPTIC TECHNOLOGY IN COMMUNICATIONS AND FOR GUIDANCE AND CONTROL [TECHNIQUES DE POINTE EN MATIERE DE FIBRES OPTIQUES DANS LE DOMAINE DES COMMUNICATIONS ET POUR LE GUIDANGE ET LE PILOTAGE]

May 1992 175 p Lectures held in Rome, Italy, 18-19 May 1992, in Leiden, Netherlands, 21-22 May 1992, and in Monterey, CA, 26-27 May 1992
(AGARD-LS-184; ISBN-92-835-0673-1; AD-A254693) Copyright Avail: CASI HC A08/MF A02

Fiber-optics is progressively changing from the research stage to the field of application. However, new possibilities are emerging, which will bring a new revolution in the field of telecommunications, such as coherent transmission, new transmission material transparent to mid-infrared radiation, active fibers, and soliton propagation. Fiber-optics is gaining increasing importance in tactical missile and aircraft guidance and control. This has been driven by the commercial development of fiber optic cable and related components. The requirements for military guidance and control applications are highly demanding for the characteristics of fibers and necessary related components (transmitters, receivers, connectors, etc.). For individual titles, see N92-28085 through N92-28093.

N92-28085# California Inst. of Tech., Pasadena, CA.

SEMICONDUCTOR LASERS AND FIBER LASERS FOR FIBER-OPTIC TELECOMMUNICATIONS

KERRY J. VAHALA, NAMKYOO PARK, JAY DAWSON, and STEVE SANDERS *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 8 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A02/MF A02

The performance characteristics of state of the art semiconductor lasers for fiber telecommunication systems are reviewed. Modulation speed, intensity noise, single frequency line width, and tunability are addressed. In addition, recent results concerning the same characteristics in single frequency, tunable fiber lasers are reviewed and compared with the semiconductor laser. Author

N92-28086# Fondazione Ugo Bordoni, Rome (Italy).

COHERENT COMMUNICATIONS

G. DEMARCHIS *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 22 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A03/MF A02

Coherent lightwave techniques, when compared to direct detection techniques, offer nearly quantum noise limited sensitivity as well as fine tunability similar to that obtained at radio frequencies. These two aspects provide communication systems planners and engineers a means to better exploit the huge bandwidth of single mode optical fibers. Field trials have been performed showing that such techniques are suitable for transmitting multigigabit per second signals to distances exceeding well over a hundred kilometers. On the other hand, coherent multichannel, frequency division multiple access, local area networks have been proposed and experimented with worldwide. This paper will discuss the theoretical advantages and limitations of the various modulation and detection formats together with the state of the art. Moreover some aspects, related to the introduction of coherent systems in local and metropolitan area networks, will be treated. Finally, some experimental data will be provided and future evolution will be discussed. Author

N92-28087# Tetra Tech, Inc., San Diego, CA.

HIGH SPEED LOCAL AREA NETWORKS

H. HODARA and E. MILES *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 12 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A03/MF A02

Radical changes are taking place in the computer architecture landscape. The big mainframes are being replaced by networks of microcomputers distributed over a wide geographical area. Increases in the speed and memory of computers has created a need for a communication medium capable of transmitting data at a rate exceeding gigabits per second. The low loss, low dispersion optical fiber is the breakthrough that makes high data rate transmission a reality. H.A.

N92-28529# Thomson-CSF, Malakoff (France).

INTEREST IN REAL-TIME SIMULATIONS FOR THE DEVELOPMENT TERRAIN FOLLOWING FUNCTION OF RADAR SYSTEMS [INTERET DES SIMULATIONS 'TEMPS REEL' POUR LE DEVELOPPEMENT DE LA FONCTION SUIVI DE TERRAIN DES SYSTEMES RADAR]

T. MARTINET *In* AGARD, Piloted Simulation Effectiveness 5 p (SEE N92-28522 19-01) Feb. 1992 In FRENCH; ENGLISH summary
(AGARD-CP-513) Copyright Avail: CASI HC A01/MF A03

During a penetration mission, modern tactical aircraft have to fly over regions with heavy electromagnetic environments. To realize such a mission, a minimum knowledge of terrain elevation is needed. Terrain elevation knowledge can be obtained from real time sensors such as radar. The development of terrain following function becoming more and more complicated, it necessitates the use of simulations to analyze the performance of sophisticated data processing and flight control. The aim of this paper is to demonstrate the contribution of interactive real time simulations during the phase of development to optimize radar resources management, in different types of terrain and many configurations of electronic warfare. It is then shown how the operational people can take part to the definition of the radar to obtain the most appropriate comportment. It is finally described how to characterize the radar performances in the complete weapon system and observe the manifestation of error simulation on the security of the system. Author

N93-13049# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.

FUNDAMENTALS AND SPECIAL PROBLEMS OF SYNTHETIC APERTURE RADAR (SAR) [LES ASPECTS FONDAMENTAUX ET LES PROBLEMES SPECIFIQUES AUX RADARS A OUVERTURE SYNTHETIQUE (SAR)]

Aug. 1992 196 p Lecture series held in Bad Neuenahr, Germany, 5-6 Oct. 1992, in Gebze-Kocaeli, Turkey, 8-9 Oct. 1992, and in Ottawa, Ontario, 26-27 Oct. 1992
(AGARD-LS-182; ISBN-92-835-0683-9; AD-A255697) Copyright Avail: CASI HC A09/MF A03

The influence of the antenna parameters on specification and capabilities of SAR and the advantages, necessities, and limits will be considered. Digital SAR processing is indispensable for SAR. Theories and special algorithms will be given along with basic processor configurations and different processing techniques on a hardware and software basis. The simulation of SAR-systems as well as SAR-products will also be a topic of the Lecture Series. A presentation of the present state of the art, giving examples of presently planned and realized airborne and spaceborne SAR with its foreseen applications will conclude the Lecture Series. This Lecture Series was sponsored by the Avionics Panel of AGARD and the Consultant and Exchange Program of AGARD. For individual titles, see N93-13050 through N93-13060.

N93-13050# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Inst. fuer Hochfrequenztechnik.
BASIC PRINCIPLES OF SAR
WOLFGANG KEYDEL *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 13 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A03/MF A03
The basic principles of SAR will be explained. Equations for geometric and radiometric resolution and their inter-relations will be given in addition to a range equation. The difference between focussed and unfocussed SAR and the conception of beam sharpening will be explained. Author

N93-13051# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Inst. fuer Hochfrequenztechnik.
SAR PECULIARITIES, AMBIGUITIES AND CONSTRAINTS
WOLFGANG KEYDEL *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 10 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A02/MF A03
A synthetic aperture radar (SAR) is basically a coherent scatterometer that employs a coherent real aperture radar with highly sophisticated data evaluation and image processing capabilities. Therefore, the coherence of the system is very important; furthermore, the keypoints for SAR are data storage, evaluation, and processing. These facts entail peculiarities of SAR and special ambiguities which are different from those arising with real aperture radar (RAR). The objective of this paper is to point out the special peculiarities and ambiguities of SAR in comparison to the corresponding properties of RAR. Main topics in this connection are as follows: basic peculiarities like range dependency of signal to noise ratio; azimuth resolution; influence of platform velocity; range and azimuth ambiguities; pulse repetition frequency limitations; velocity effects; and phase error influence, on SAR-image, that can cause motion compensation problems. All these effects will be explained together with different contrast-equations between the target and clutter signals of SAR and RAR. Author

N93-13052# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Inst. fuer Hochfrequenztechnik.
MOTION ERRORS AND COMPENSATION POSSIBILITIES
DAVID HOUNAM *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 12 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A03/MF A03
The synthetic aperture radar (SAR) technique relies on knowledge of the relative motion between the sensor and the target. If the flight path of the sensor is not accurately known or the SAR processor is limited in its ability to take the flight data into account, the SAR image will be degraded. Motion errors are particularly critical for SAR sensors on small, low-flying aircraft, due to turbulence, and where high spatial resolution is required. The lecture discusses the effects of motion errors on image quality and the requirements on the sensor and processor to compensate for motion errors. The DLR airborne sensor, E-SAR, and associated image processor will be used as examples. Techniques using a priori knowledge of the flight path from independent sensors, e.g., inertial navigation systems (INS), and by extracting the flight data from the SAR data, e.g., autofocus and reflectivity displacement method (RDM), are treated. Author

N93-13053# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Inst. fuer Hochfrequenztechnik.
THE REAL APERTURE ANTENNA OF SAR, A KEY ELEMENT FOR PERFORMANCE
HERWIG OETTL *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 8 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A02/MF A03
For a SAR system flying on an airborne or spaceborne platform, the real antenna must be designed in such a way so as to avoid ambiguities and achieve the envisaged resolution. Although a SAR is, with respect to geometric azimuth resolution, independent of its distance from a target, the ground range resolution depends on the incidence angle and, of course, on the bandwidth dependent slant range resolution. The antenna size and its half power beam width (HPBW) in azimuth and elevation define its azimuth resolution and, for a given off-nadir angle and chosen altitude, the swath width. The minimum antenna size, measured in wavelengths, depends on the altitude, velocity of the platform, and chosen off-nadir angle. In real antenna design, the aperture size will be somewhat larger in order to allow for amplitude taper (at least in elevation), for electronic beam steering and possibly for beam shaping. This paper explains the interdependence of antenna parameters with SAR system performance. Author

N93-13054*# Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA.
POLARIZATION EFFECTS AND MULTIPOLARIZATION SAR
ANTHONY FREEMAN *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 13 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A03/MF A03
Imaging radar polarimeters are usually implemented using a Synthetic Aperture Radar (SAR) approach to give a high resolution image in two dimensions: range and azimuth. For each pixel in the image a polarimetric SAR gives sufficient information to characterize the polarimetric scattering properties of the imaged area (or target) as seen by the radar. Using a polarimetric SAR system as opposed to a single-polarization SAR system provides significantly more information about the target scattering mechanisms and allows better discrimination between different types of surfaces. In these notes a brief overview of SAR polarimetry is offered. The notes are intended as a text to accompany a lecture on SAR polarimetry as part of an AGARD-NATO course. Covered in the notes are the following: the polarization properties of electromagnetic waves; the concepts of radar scattering and measuring radar backscatter with a SAR; polarization synthesis; scattering matrix, Stokes matrix, and covariance matrix representations of polarimetric SAR data; polarization signature plots; design and calibration of polarimetric SAR systems; polarization filtering for target detection; fitting a simple model to polarimetric SAR measurements of naturally occurring features; and supervised classification of polarimetric SAR data. Author

N93-13055# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Inst. fuer Hochfrequenztechnik.
RADIOMETRIC CALIBRATION OF SAR SYSTEMS
HERWIG OETTL *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 9 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A02/MF A03
Most SAR image interpretation performed in recent years was based on data which were often insufficiently calibrated. Ground truth data were used for comparison and interpretation. The importance of calibration was recognized by the need for reproducible data, by the introduction of multifrequency and multipolarization systems (interchannel calibration), and the long term scope of remote sensing. Hydrologists, especially, requested an absolute calibration with tolerances of less than 1 dB. Internal calibration schemes, as well as the use of external passive and active calibrators, were introduced to achieve this goal over the wide dynamic range. The in-flight measurement of the antenna pattern by means of ground based receivers became increasingly important due to pattern changes caused by electronic beam steering and the necessity of beam alignment in case of multifrequency and/or polarimetric operation modes. The use of radiometric corrections to compensate for near range/far range differences caused by the antenna pattern and geometry of illumination will be explained in the lecture. The impact of geocoding on radiometric levels will also be mentioned, including the phenomenon of over-/underexposing hilly regions, caused by incidence angle changes. Author

N93-13056# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Inst. fuer Hochfrequenztechnik.
SAR SIMULATION
DAVID HOUNAM *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 16 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A03/MF A03

The use of software tools as an investigative method is particularly important in the case of synthetic aperture radar sensors, as the geometry cannot be reproduced in the laboratory. Also, the complete SAR system, from the target via the propagation path, sensor and image processor to the final image, represents a highly complex data chain, which cannot be treated in part. The lecture discusses different approaches from parametric analysis tools to full-blown simulators capable of analyzing all elements of the SAR system. The latter will be illustrated with the aid of the SARSIM simulator, which was used for confirming parameters of the ERS-1 Active Microwave Instrument (AMI). Particular emphasis will be placed on the simulation of target scattering mechanisms, the understanding of which is essential if the potential of SAR systems is to be fully exploited, and on the modelling of sensor characteristics. Author

N93-13057*# Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA.
MULTI-FREQUENCY MULTI-POLARIZATION PROCESSING FOR SPACEBORNE SAR
JOHN C. CURLANDER and C. Y. CHANG *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 7 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A02/MF A03

The Shuttle Imaging Radar-C (SIR-C) is the third in a series of space shuttle based synthetic aperture radars (SAR) sponsored by the National Aeronautics and Space Administration (NASA). The SIR-C ground data processing system is to process the playbacked SAR signal data into a variety of data products for distribution to the science community. An overview of the end-to-end ground data processing system with emphasis on the unique characteristics involved in the system design is presented. Included in the discussion are science requirements, radar system specifications, input data format specifications, system operations design, data products design, processing algorithm design, hardware architecture design, and software design. Author

N93-13058# Thomson-CSF, Malakoff (France).
INVERSE SYNTHETIC APERTURE RADAR
JEAN-PHILIPPE HARDANGE *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 14 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A03/MF A03

ISAR is a technique, based on time and Doppler frequency analysis, which is used for imaging of targets having rotational motions with regard to the radar. In the sixties, observation of the Moon and planets by a radar located on the Earth was one of the first applications. Closely derived from these first trials, imaging of objects in terrestrian orbit by ISAR techniques is performed with interesting results. However, the most current domains of application of ISAR are now measurements of target signatures and target recognition. Author

N93-13059# Canada Centre for Remote Sensing, Ottawa (Ontario). RADARSAT Project Office.
SPECIAL SAR TECHNIQUES AND APPLICATIONS
R. KEITH RANEY *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 15 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A03/MF A03

SAR systems as considered in these lectures are fully coherent and are characterized by large time/bandwidth signal structure in both range and azimuth. These properties allow additional and specialized performance to be achieved through innovative system variations. Author

N93-13060# Canada Centre for Remote Sensing, Ottawa (Ontario). RADARSAT Project Office.
REVIEW OF SPACEBORNE AND AIRBORNE SAR SYSTEMS
R. KEITH RANEY *In* AGARD, Fundamentals and Special Problems of Synthetic Aperture Radar (SAR) 20 p (SEE N93-13049 03-32) Aug. 1992
(AGARD-LS-182) Copyright Avail: CASI HC A03/MF A03

This Lecture provides a concise summary of the state of the art in SAR systems, both spaceborne and airborne. The first civilian SAR mission in space was the United States' SEASAT (L-band), operating Jul. - Sep. 1978. It was followed by two Shuttle missions of one week duration each, SIR-A (L-band, Nov. 1981), and SIR-B (L-band, Oct. 1984). The 1990's are witnessing a flurry of orbital SAR activity, with Almaz (USSR, S-band, Mar. 1991), ERS-1 (ESA, C-band, Jul. 1991), J-ERS-1 (Japan, L-band, Feb. 1992), SIR-C/X-SAR (USA/Germany and Italy, L-, C- and X-bands, three launches planned after 1993), ERS-2 (ESA, repeat mission), and RADARSAT (Canada, C-band, 1995) taking place in the decade. System parameters are included in Tables, and general characteristics of these radars are compared and contrasted. The lecture also provides an overview of airborne SAR systems, including those of NASA (USA), CCRS (Canada), Intera/MDA (Canada), DLR (Germany), and TUD (Denmark), among others. Author

N93-19771# Istanbul Univ. (Turkey).
ADVANCES IN SPEECH PROCESSING
A. NEJAT INCE *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 14 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A03/MF A03

The field of speech processing is undergoing a rapid growth in terms of both performance and applications and this is fueled by the advances being made in the areas of microelectronics, computation, and algorithm design. The use of voice for civil and military communications is discussed considering advantages and disadvantages including the effects of environmental factors such as acoustic and electrical noise and interference and propagation. The structure of the existing NATO communications network and the evolving Integrated Services Digital Network (ISDN) concept are briefly reviewed to show how they meet the present and future requirements. The paper then deals with the fundamental subject of speech coding and compression. Recent advances in techniques and algorithms for speech coding now permit high quality voice reproduction at remarkably low bit rates. The subject of speech synthesis is next treated where the principle objective is to produce natural quality synthetic speech from unrestricted text input. Speech recognition where the ultimate objective is to produce a machine which would understand conversational speech with unrestricted vocabulary, from essentially any talker, is discussed. Algorithms for speech recognition can be characterized broadly as pattern recognition approaches and acoustic phonetic approaches. To date, the greatest degree of success in speech recognition has been obtained using pattern recognition paradigms. It is for this reason that the paper is concerned primarily with this technique. Author

N93-19925# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Direction des Etudes de Synthese.
RAMSES: MULTI-SPECTRAL EXPERIMENTAL RADAR STATION INSTALLED ON BOARD THE TRANSALL [RAMSES: STATION RADAR EXPERIMENTALE MULTI-SPECTRALE EMBARQUEE SUR TRANSALL]
J. M. BOUTRY and D. LECOZ *In* AGARD, Flight Testing 8 p (SEE N93-19901 06-05) Oct. 1992 In FRENCH
(AGARD-CP-519) Copyright Avail: CASI HC A02/MF A04

Within the context of studies devoted to onboard radar applications (missiles, aircraft, satellites, etc.), ONERA is developing and implementing, with the support of the General Delegation for Armament and in collaboration with the Flight Testing Center of Bretigny, a radar experimental station installed onboard a Transall. This permits a parametric study of the radar operating modes and the associated methods of signal processing. The areas in which the station is used are introduced, while examining in particular the problem of the transposition of the radar and geometric parameters. Then, the main technical features of the station are reviewed. Finally, a few examples of the preliminary results are described. Author

N93-22019# Naval Air Warfare Center, China Lake, CA. Weapons Div.

ELECTROMAGNETIC RADIATING SOURCE ELIMINATION (ERASE) PROGRAM

DON R. STAPLETON, GEORGE W. HOPPUS, and ROBERT E. SUTTON *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 4 p (SEE N93-22018 08-31) Nov. 1992

(AGARD-CP-524) Copyright Avail: CASI HC A01/MF A02

The ERASE program has been for many years a principle source of advanced research and development work within the U.S. Department of Defense in support of the lethal defense suppression warfare mission area. Projects conducted at the U.S. Naval Weapons Center, China Lake, California (now part of the U.S. Naval Air Warfare Center), under the ERASE program, have been remarkably successful in both discovering and proving new technologies needed in lethal defense suppression, and in working with industry to transition this technology to fleet weapons prepared to support U.S. and NATO forces. Author

N93-22024# Bilkent Univ., Ankara (Turkey).

MULTIVARIABLE FREQUENCY RESPONSE METHODS FOR OPTIMAL KALMAN-BUCY FILTERS WITH APPLICATIONS TO RADAR TRACKING SYSTEMS

C. C. ARCASOY *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 14 p (SEE N93-22018 08-31) Nov. 1992

(AGARD-CP-524) Copyright Avail: CASI HC A03/MF A02

The problem of multi-output, infinite-time, linear time-invariant optimal Kalman-Bucy filter both in continuous and discrete-time cases in frequency domain is addressed. A simple new algorithm is given for the analytical solution to the steady-state gain of the optimum filter based on a transfer function approach. The algorithm is based on spectral factorization of observed spectral density matrix of the filter which generates directly the return-difference matrix of the optimal filter. The method is more direct than by algebraic Riccati equation solution and can easily be implemented on digital computer. The design procedure is illustrated by examples and closed-form solution of ECV and ECA radar tracking filters are considered as an application of the method. Author

N93-22030# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany).

RADAR SEEKER BASED AUTONOMOUS NAVIGATION UPDATE SYSTEM USING TOPOGRAPHY FEATURE MATCHING TECHNIQUES

H. D. LERCHE and F. TUMBREAGEL *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 13 p (SEE N93-22018 08-31) Nov. 1992

(AGARD-CP-524) Copyright Avail: CASI HC A03/MF A02

The discussed navigation update system was designed for an unmanned platform with fire and forget capability. It meets the requirement due to fully autonomous operation. The system concept will be characterized by complementary use of the radar seeker for target identification as well as for navigation function. The system works in the navigation mode during preprogrammable phases where the primary target identification function is not active or in parallel processing. The dual function radar seeker system navigates the drone during the midcourse and terminal phases of the mission. Its high resolution due to range measurement and doppler beam sharpening in context with its radar reflectivity sensing capability are the basis for topography referenced navigation computation. The detected height jumps (coming from terrain elevation and cultural objects) and radar reflectivity features will be matched together with topography referenced features. The database comprises elevation data and selected radar reflectivity features that are robust against seasonal influences. The operational benefits of the discussed system are as follows: (1) the improved navigation performance with high probability of position fixing, even over flat terrain; (2) the operation within higher altitudes; and (3) bad weather capability. The developed software modules were verified with captive flight test data running in a hardware-in-the-loop simulation. Author (revised)

N93-23598# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.

RADIOLOCATION TECHNIQUES [LES TECHNIQUES DE RADIOLOCALISATION]

Nov. 1992 346 p Symposium held in London, England, 1-5 Jun. 1992 Original contains color illustrations

(AGARD-CP-528; ISBN-92-835-0695-2; AD-A263505; AD-A265099) Copyright Avail: CASI HC A15/MF A03

Modern defense systems must have a comprehensive surveillance capability. A key component of a surveillance system is the ability to detect and to locate radio signals in the entire radio spectrum from extremely low frequencies through millimeter wavelengths. Various techniques are used to determine the angle of arrival of a radio signal and the distance to the source. This often involves complex signal processing techniques. The symposium addressed first propagation aspects with emphasis on ionospheric characteristics and effects. Two sessions were devoted to the description of radio location techniques such as single site location and another two to radio location measurements and systems. One session covered signal processing techniques in radio location applications. One session covered classified subjects and will be published in a classified addendum. For individual titles, see N93-23599 through N93-23631.

N93-23599# Wait (James R.), Tucson, AZ.

LATERAL DEVIATION OF VLF RADIO WAVES DUE TO DIFFRACTION AND SCATTERING FROM COAST-LINES, MOUNTAIN RANGES, AND POLAR ICE CAPS

JAMES R. WAIT *In* AGARD, Radiolocation Techniques 12 p (SEE N93-23598 08-32) Nov. 1992

(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03

This paper deals with a physical theory of radio wave propagation in the earth ionosphere waveguide when allowance is made for lateral non-uniformities in the lower boundary. A combined hybrid ray and mode analysis is adopted which reduces to the now conventional formulation when the lower boundary is uniform. For obvious reasons, the mathematical details will not be presented but the optical interpretation is given and the physical concepts are illustrated in a meaningful fashion. A case of particular interest is when the global propagation of the VLF signal arrives from both the direct path as well as a sometimes very strong resonant scatter from a continental mountain range 1000 km or more off the great circle path. Other examples occur when the signal actually diffracts around convex coast-lines and continental margins such as the Antarctic ice cap. In such cases, the direct path signal over the highly lossy medium is highly attenuated and may be out of contention. In the simplest theory of 'horizontal bending' of VLF wave guide modes, the conversion of modes, of one order to another, is ignored. But, by employing mode match techniques, the conversion of modes of order m to modes of order n (reflected) and to modes of order p(transmitted) can be estimated. Both a scalar and a vector version of the formulation are outlined. Actually the scalar version is really more appropriate for dealing with acoustic ducts with inhomogeneous walls when the horizontal direction of propagation is oblique to the junction planes. Strictly speaking the full blown vector problem must be dealt with in the electromagnetic case if proper allowance is to be made for the inevitable coupling between the TM (transverse magnetic) and TE (transverse magnetic) modes. Author (revised)

N93-23600# Phillips Lab., Hanscom AFB, MA. Geophysics Directorate.

PROPAGATION CHARACTERISTICS OF THE IONOSPHERIC TRANSMISSION WINDOW RELATING TO LONG WAVE RADIO LOCATION ISSUES

PAUL A. KOSSEY and EDWARD A. LEWIS (Systems Integration Engineering, Inc., Lexington, MA.) *In* AGARD, Radiolocation Techniques 17 p (SEE N93-23598 08-32) Nov. 1992

(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03

Most applications of long radio waves (ELF/VLF/LF/MF) are ground-based and exploit the fact that such signals can propagate to great distances via reflections from the lower ionosphere. It is known however that, owing to the influence of the earth's magnetic field, long wave signals can penetrate through the ionosphere as well; at times, the waves penetrate with relatively little loss, depending on ionospheric conditions and other propagation factors. This has prompted investigations of the long wave 'ionospheric

transmission window' as part of efforts to assess the feasibility of deploying long wave emitters in space for terrestrial applications and/or for exploiting, in space, signals emanating from ground-based long wave transmitters. This paper outlines results of theoretical and experimental investigations of the ionospheric transmission window over the frequency range from about 100 Hz to 500 kHz, with emphasis on directional issues associated with long wave penetration of the ionosphere. Author (revised)

N93-23601# General Research Corp., Albuquerque, NM.
THE EFFECTS OF MULTIPATH SCATTER FROM WIND DRIVEN GRAVITY WAVES ON LINES OF BEARING SERVING AS DIRECTION FINDERS
R. H. OTT *In* AGARD, Radiolocation Techniques 6 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

Unambiguous locations for target transmitters are based on lines of bearing (LOB's) obtained by radio direction finding (DF) methods. These target location estimates based on intercepted LOB's are subject to error if multipath exists. This multipath may result from sky wave interference or sea scatter from rough seas. Sky wave multipath becomes important for ranges greater than 300 km while ground wave multipath may be significant for ranges less than about 100 km. Although, the groundwave loss may be greater than the one-hop sky wave mode, it may be comparable to the loss associated with the two-hop mode. Therefore both groundwave and sky wave multipath may contribute to LOB errors for a given fleet exercise. For the case of sky wave multipath, newer DF systems will be able to differentiate sky wave signals from ground wave signals when the elevation angle is greater than about 18 deg. In this paper, groundwave multipath is estimated using the compensation theorem. This method provides a convenient analytical tool for relating the change in mutual impedance between a transmitting monopole and a receiving loop over a rough sea surface and a flat sea. The change in mutual impedance, in turn, is related to the change in current in each of the receiving loops used to generate LOB's. Some predicted and observed examples of fleet exercise LOB errors from wind generated swell will be given based on target transmitter frequency, wind direction, and speed of the ship carrying the DF system. Author (revised)

N93-23602# Syracuse Research Corp., NY.
PROPAGATION EFFECTS ON HF DIRECTION FINDING
GEORGE H. MILLMAN *In* AGARD, Radiolocation Techniques 12 p (SEE N93-23598 08-32) Nov. 1992
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Estimates are made of the propagation errors that can be made in the measurement of the geographic coordinates of an HF emitter when utilizing HF direction finding techniques. The sources of the errors considered in this analysis are those due to the following: (1) imprecise knowledge of the ionospheric reflection height; (2) ionospheric tilts, i.e., gradients of electron density; and (3) tropospheric refractive bending. Author (revised)

N93-23603# Paris-Sud Univ., Orsay (France).
NEW METHOD OF MODELLING THE MESOSCALE STRUCTURE OF THE IONOSPHERE WITH A SINGLE SENSOR. IMPACT ON HF RADIO-LOCATION [NOUVELLE METHODE DE MODELISATION MESO-ECHELLE DE L'IONOSPHERE A PARTIR D'UN SITE UNIQUE. APPLICATION A LA RADIOLOCALISATION HF]
J. L. MOKRZYCKI, L. BARTHES, J. CARATORI, and C. GOUTELARD *In* AGARD, Radiolocation Techniques 13 p (SEE N93-23598 08-32) Nov. 1992 In FRENCH
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Modeling of the ionosphere is a necessity in numerous applications: the physical study of an area, telecommunications, transhorizon radars, and radio location. Radio location from a single sensor is particularly attractive but requires, in the decametric propagation range, knowledge with a sufficient precision of the ionospheric area within which the trajectories of the radii are controlled, not only by the vertical profile of the ionization, but also by the horizontal gradient. A tracing of a radius in an ionosphere is investigated by making use of a Bradley-Dudeney model in the presence of horizontal gradients whose transversal components are not null. One can see that the components draw the propagations outside of a large circle with important deviations on the ground due to the reflection occurring in region F. Taking into account these gradients is indispensable for a correct location, which makes their estimation necessary. Radio location from a single sensor necessitates therefore the placement in the same location of a means of measurement. A retrodiffusion probe easily brings anisotropies to light. It represents a simple means which is possible to put to work with very little power and is therefore attractive. The principal difficulty of this technique is in the resolution of an inverse problem which, aside from the measurements obtained, permits the discovery at all points of the observation zone of the vertical profile from which the gradients are deduced. It is a difficult problem which has not yet really received a totally satisfactory solution in spite of important efforts produced by the scientific world. The stabilization of the solution appears to be possible thanks to new techniques which allow the measurement of new parameters. The angle of elevation of retrodiffused radii is one of these parameters, the importance of which was predicted during the 1960's. The utilization of this parameter, together with the data furnished by a retrodiffusion probe, permitting the observation of all azimuths, is developed in this presentation. Author (revised)

N93-23604# Rome Lab., Hanscom AFB, MA. Electromagnetics and Reliability Directorate.
THE SPATIAL AND TEMPORAL CHARACTERISTICS OF HIGH FREQUENCY AURORAL BACKSCATTER
D. S. CHOI, BERT WEIJERS, R. J. NORRIS, and N. B. MYERS *In* AGARD, Radiolocation Techniques 10 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

Preliminary results from the measurements of high frequency (HF) backscattered signals from the auroral ionosphere using the Verona-Ava Linear Array Radar (VALAR) system are presented. VALAR is an experimental HF backscatter system capable of obtaining high resolution synoptic mapping of HF signals backscattered from field-aligned electron density irregularities in the auroral ionosphere. The receive system includes a 700 meter long linear array, providing the high azimuthal resolution required for determining the spatial distribution of HF auroral backscatter. Since the completion of the system tests and calibration at the end of 1989, experimental campaigns have been carried out on a near-monthly basis. In this paper, we provide a brief description of VALAR and present preliminary measurements of three types of phenomena: ground backscatter, slant-F, and auroral backscatter. Author (revised)

N93-23605# Boston Univ., MA. Center for Space Physics.
THE LONGITUDINAL OCCURRENCE OF EQUATORIAL F LAYER IRREGULARITIES
JULES AARONS *In* AGARD, Radiolocation Techniques 12 p (SEE N93-23598 08-32) Nov. 1992 Sponsored by ONR
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03

Determining the morphology of F layer irregularities as a function of longitude in the equatorial region is vital for understanding the physics of the development of these irregularities. We aim to lay the observational basis which then can be used to test theoretical models. The question is whether the models are consistent with the morphology as we see it. According to our criteria, the data used should be confined to observations taken near the magnetic equator during quiet magnetic equator during quiet magnetic periods and at times within a few hours after sunset. Anomaly region data should be omitted for studying the generation mechanism. The questions to be answered by proposed mechanisms are (1) why do the equinox months have high levels of occurrence over all longitudes?; (2) why are there relatively high levels of occurrence in the Central Pacific Sector in the Jul.-Aug. period and in the 0-75 degree West Sector in the Nov.-Dec. period?; and (3) why are these very low levels of occurrence in Nov. and Dec. in the Central Pacific Sector and in Jul. and Aug. in the 0-75 degree West Sector? Satellite in-situ data, scintillation and spread F observations are reviewed. The limitation of each data set is outlined particularly as relevant to the bias produced by the existence of thin versus extended layers of irregularities. A cartoon of the occurrence pattern, as we see it, as a function of longitude is shown. Author (revised)

N93-23606# Nebraska Univ., Lincoln, NE. Dept. of Electrical Engineering.
IRREGULAR MEDIA EFFECTS ON RADIOWAVE SIGNALS USED IN NAVIGATION AND POSITIONING SYSTEMS
EZEKIEL BAHAR *In* AGARD, Radiolocation Techniques 12 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03

Radiowave signals, over a very broad range of frequencies, are used extensively in navigation and propagation systems. These signals that propagate to very large distances from the transmitter across the earth's surface or through the ionosphere are significantly affected by media irregularities. Some of these irregularities are fixed while others fluctuate due to, for instance, the diurnal variations in the ionosphere. The magnitude and phase of CW signals are affected by the medium through which they propagate. Since these effects are frequency dependent, transient (pulsed) signals also undergo distortions and delays, which have a very significant impact on navigation and positioning systems. Thus, when CW signals are used for navigation or positioning, it is necessary to predict the deviations in the phase of the received signals (phase anomalies) due to medium effects. When pulsed signals are used for navigation and positioning, it is necessary to predict the signal delays due to the medium effects. Moreover, for given propagation paths, it is necessary to avoid the use of carrier frequencies that are more prone to signal distortions which make it very difficult to predict the time of arrival of the radio signals. It is necessary to obtain accurate predictions of the received signals as the demands on the navigation system become more stringent. Thus, for most relevant propagation problems, it is not sufficient to use idealized models of the propagation medium. The models that need to be considered consist of layers of nonuniform thickness with varying electromagnetic parameters. Since the ionosphere also needs to be considered, the medium is generally considered to be both inhomogeneous and anisotropic. For these irregular models of the curved earth-ionosphere propagation environment, it is not possible to obtain standard separable solutions for the propagation problem. Furthermore, since the solutions should be valid for a very broad range of radio frequencies, the physical/geometrical optics (high frequency) approach or the small perturbation (low frequency) approach cannot be used in general. In this work, a full-wave approach is described in detail. Radio wave propagation over irregular propagation paths is examined in detail. The phase anomalies and pulse delays and distortions for radio signals transmitted across hills and valleys on the earth's surface or over the oceans and through irregular layered models of the earth's crust and the ionosphere are determined using the full-wave approach. Author

N93-23607# Rennes Univ. (France). Lab. Radiocommunications.
THE INFLUENCE OF PROPAGATION ON HIGH FREQUENCY RADIOGONIOMETRY AND SINGLE STATION LOCATION [INFLUENCE DE LA PROPAGATION SUR LA GONIOMETRIE HAUTE FREQUENCE ET LA LOCALISATION A STATION UNIQUE]
V. BALTAZART, L. BERTEL, and R. FLEURY (Centre National d'Etudes des Telecommunications, Lannion, France.) *In* AGARD, Radiolocation Techniques 13 p (SEE N93-23598 08-32) Nov. 1992 In FRENCH
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03

This paper deals with some propagation effects which can influence Single Station Location systems. We consider first, the direct problem which consists of estimating several directions of arrival of the incoming waves. For this purpose and for a given state of the ionospheric medium, the angles of all propagation paths and modes are determined. In a second step, the simplified model of waves coming from the ionosphere which has been developed before, permits us to simulate the behavior of radiogoniometers. We analyze the performance of goniometric systems based upon interferometry, data processing, and space-time processing. Proximity in such propagation modes leads to the addition of a polarization filtering procedure. The problem in reverse consists of locating the emitter thanks to the previous radiogoniometry results. We look at the effect of an imperfect knowledge of the profile, before introducing two SSL methods: the first dealing with vertical sounding results; and the second works from a partial updating profile. We also give an example of an influence of tilt. Author

N93-23608# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Ionospheric Branch.
A CURRENT ASSESSMENT OF SINGLE SITE LOCATING TECHNOLOGY
ROBERT B. ROSE *In* AGARD, Radiolocation Techniques 8 p (SEE N93-23598 08-32) Nov. 1992
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This paper describes the observed performance of a HF Single Site Locator (SSL) which employs current interferometer technology. One hundred and forty two locations were obtained from non-cooperative targets over a five day period in April 1989. Locations were determined from fast, high resolution azimuth and elevation angle of arrival measurements and a knowledge of the ionospheric reflecting medium. Exact emitter locations were determined post facto with ground truth data from the field units. Five modes of transmission were encountered and the signals were successfully located. Miss distance accuracies varied between 12.5 kilometers to 40.5 kilometers over ranges that varied from 109 kilometers to 526 kilometers. Performance varied as a function of modulation type with SSB voice being the most difficult to prosecute and packet, and burst signals were the easiest to locate. Also, performance varied as a function of range and the relationship of the operating frequency to the maximum usable frequency between the SSL and the target. Author

N93-23609# Southwest Research Inst., San Antonio, TX. Electromagnetics Div.
A NEW PASSIVE SSL TECHNIQUE FOR HF RADIOLOCATION
R. L. JOHNSON, Q. R. BLACK, and A. G. SONSTEBY *In* AGARD, Radiolocation Techniques 8 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

This paper considers the problem of passive radio location for the case of HF multipath propagation. A new technique is developed for the estimation of interpath time delay applying an eigen based super-resolution spectral estimation method. The technique samples the wavefield received by two spatially separated antennas to compute intersensor delay time for each constituent signal through a normalized eigen cepstral analysis. The intersensor delays and interpath delay are used in concert to estimate the location of the transmitter. The method is applied to experimental data in a preliminary proof-of-concept analysis. Author

N93-23610# Andrew SciComm, Inc., Garland, TX.
PROCEDURES FOR DETERMINING THE LOCATION OF AN HF RADIO TRANSMITTER
LEO F. MCNAMARA *In* AGARD, Radiolocation Techniques 12 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03

The location of an HF transmitter may be derived by either of two methods, depending on what observations of the target transmitter are available. In the traditional approach currently adopted for strategic DF networks, the location is determined by triangulation using Lines of Bearing (LOB) of the signals observed at two or more HF-DF sites. This approach is called the LOB approach. Alternatively, the location may be derived by observations at a single DF site, if the observations are extended to include that of the elevation angle as well as the bearing of the incoming radio waves. Triangulation in the vertical plane containing the observed LOB, using a model of the propagation medium (the ionosphere), leads to an estimate of the position of the target transmitter. This approach is known as the Single Site Location (SSL) method. The success of the LOB approach depends heavily on two or more DF sites being able to hear and process the signals from the target transmitter, as well as on having reasonably favorable geometries. When these conditions are not met, the LOB approach fails. The SSL method, on the other hand, is applicable under almost all conditions. This paper, therefore, compares and contrasts the two approaches to determining the location of an HF transmitter. The relative advantages of the SSL approach are shown to be such that all HF-DF sites should logically be SSL sites. Author

N93-23611# Defence Research Establishment Ottawa, Ottawa (Ontario).
HIGH RESOLUTION SAMPLED APERTURE ARRAY DIRECTION FINDING AT HF
T. N. R. COYNE *In* AGARD, Radiolocation Techniques 8 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

A simple parametric target model fitting algorithm that gives a least squares fit to the observed in-phase and quadrature data across a linear sampled aperture array is outlined. The performance of this algorithm with various simulated signals and noise levels is presented. In particular, it is shown that this approach is quite robust in the presence of noise. The algorithm was developed for the analysis of data obtained on a large HF sampled aperture receiving array operated near Ottawa. An example of this analysis is given. In this instance, a long range signal exhibiting typical ionospheric fading (on individual array elements) is shown to be resolvable into three stable, coherent components spread over a 2.5 degree arc. Author

N93-23612# GEC-Marconi Electronics Ltd., Chelmsford (England).
DETECTION OF ACTIVE EMITTERS USING TRIANGULATION AND TRILATERATION TECHNIQUES: THEORY AND PRACTICE
A. M. DEAN *In* AGARD, Radiolocation Techniques 7 p (SEE N93-23598 08-32) Nov. 1992 Sponsored by Defence Research Agency
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

Recent conflicts have highlighted the benefits of 'soft-kill' electronic warfare (stand off, escort, and self screening jamming), during intrusion into areas protected by Air Defence (AD) radar networks. These conflicts have highlighted the need to protect and supplement the Recognized Air Picture (RAP) with the ability to locate and track the intruding jammers. A Passive Jammer Location (PJL) system, and some of the theory behind it, currently under development at the Marconi Research Center are described. The two basic geometrical techniques for locating unknown emitters, usually termed triangulation and trilateration, are identified. The main problems associated with triangulation techniques, those of target ghosts and ghost resolution in denser scenarios, are discussed and trilateration processing using correlation offered as a solution. The main feature of an operational PJL system is noted as being the need to positively resolve jammer positions, to sub-beam accuracy, in dense jamming scenarios. This includes the 'pop-up' target appearing over the radar horizon and the agile sophisticated jammer. In addition a number of other features are identified which would be desirable in any future NATO PJL system. Over a number of years the UK MoD and GEC-Marconi have undertaken a number of studies relating to PJL architectures and data processing techniques. In 1991 these studies led to the Air Defence Emitter Location Equipment (ADELE) Technology Demonstrator. The objectives of the ADELE program are to demonstrate that the requirements of a PJL system can be met at a price affordable by AD system procurers. Additionally to confirm that the new PJL data processing techniques, developed during these previous studies, perform as predicted during live trials. The main hardware and software modules making up the ADELE demonstrator are discussed including: the multi beam antenna, the resistive matrix beam former, the PJL multi-channel signal sampling hardware, radar interfaces and synchronization, signal and data processing, display and recording, and simulation resources. Author (revised)

N93-23613# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Ionospheric Branch.
RADIOLOCATION OF A SATELLITE-BORNE LOVHF BEACON
ROBERT B. ROSE *In* AGARD, Radiolocation Techniques 6 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

A year long experimental program was conducted to measure refractive bending, or how much the signal deviates from true line of sight, at low VHF frequencies (29.5 MHz), and to determine whether this deviation or error could be predicted using large scale ionospheric models such as the Ionospheric Conductivity and Electron Density (ICED) program. An experiment to directly measure the angle of arrival of a 29.5 MHz signal from an orbiting satellite was successfully completed. The satellite was in a circular orbit at an altitude of 1000 km. It was shown that refractive errors can be directly related to the electron density along the measurement slant range. Ionospheric disturbances such as sporadic E and ionospheric storms produce large, short term errors that can approach 10 degrees. In addition to day/night variations, seasonal and solar cycle sensitivities were found. The refractive error varied so rapidly with respect to time and space that its prediction with a median value ionospheric code is almost impossible. Author

N93-23614# Leicester Univ. (England). Dept. of Physics and Astronomy.
SYSTEMATIC BEARING ERRORS OF HF SIGNALS OBSERVED OVER A NORTH-SOUTH PROPAGATION PATH
T. B. JONES, E. M. WARRINGTON, and J. E. PERRY (Department of Defense, Washington, DC.) *In* AGARD, Radiolocation Techniques 5 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A01/MF A03

Strong gradients in electron density associated with sunrise and sunset are a well known feature of the ionosphere and will produce off great circle bearings, particularly if the propagation path is parallel to the dawn or dusk terminator. Measurements were undertaken of the direction of arrival of signals in the range 3 to 23 MHz radiated by a transmitter located at Clyde River in the Canadian Arctic (70 deg N, 70 deg W). The path from this transmitter to the receiving site at Boston, USA, is parallel to the dawn dusk line and consequently systematic changes in bearings are expected to occur. Bearings measured during January 1989 indicate a positive error of a few degrees at around sunrise. As the day progressed the error decreased, becoming zero at local noon at the path mid point. As the dusk approaches, the tilts in the ionosphere are reversed in gradient and there is a smaller negative swing in the mean bearing. The bearing error at dusk is smaller than at sunrise since the ionospheric gradients at this time are less steep. The diurnal swing in the bearing occurs during the winter and equinox periods but is absent (or very small) during summer. This is because the ionospheric gradients in summer are smaller than those at other seasons due to the relatively low values of the F-region critical frequency (foF2) which occur during the summer daytime. Author (revised)

N93-23615# Leicester Univ. (England). Dept. of Physics and Astronomy.
LARGE BEARING ERRORS OBSERVED AT A HIGH LATITUDE DF SITE
T. B. JONES and E. M. WARRINGTON *In* AGARD, Radiolocation Techniques 10 p (SEE N93-23598 08-32) Nov. 1992 Sponsored by Dept. of National Defence
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

It is well known that the auroral zone ionosphere contains steep time varying gradients in electron density which can produce large off-great circle bearings in the direction of arrival of HF radio signals reflected from this region of the ionosphere. Recent DF measurements at a high latitude site indicate that large bearing errors are also observed in signals reflected from the polar cap ionosphere which is generally regarded as being a much less disturbed region than the auroral zone. A feature of these measurements is a large (+ or - 50 deg) quasi-periodic swing in the direction of arrival observed for both short and long propagation paths. These changes in angle of arrival are attributed to reflection from patches or 'blobs' of over-dense plasma which travel with the convection current flow across the polar cap region from dayside to nightside. The periods of large bearing swings are well correlated with the onset of magnetic activity as measured by the Kp index. Author (revised)

N93-23616# Leicester Univ. (England). Dept. of Engineering.
MEASUREMENTS OF THE DIRECTION OF ARRIVAL OF AN OBLIQUE CHIRP SOUNDER SIGNAL
E. M. WARRINGTON, T. B. JONES, and P. HAMADYK *In* AGARD, Radiolocation Techniques 10 p (SEE N93-23598 08-32) Nov. 1992 Sponsored by Dept. of National Defence
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

The performance of high frequency (HF) direction finding systems is related to the mode content of the received signal and to the signal frequency. In order to fully investigate this effect, an experiment was devised to measure the direction of arrival of oblique ionospheric sounding signals emitted by the worldwide

network of BR Communications chirp sounders. These signals are radiated as a constant sweep chirp signal from 2 to 16 or 30 MHz thus enabling the DF performance to be measured over the full range of frequencies propagating from the chosen transmitter. Simultaneous oblique ionograms are also recorded for the paths of interest in order to determine the mode structure at any frequency. Preliminary tests of the system were undertaken at Ottawa, Canada and Cheltenham, UK with the directions of arrival measured by a wide aperture goniometric DF system. Several interesting features were identified in these measurements. A further measurement campaign was conducted during Apr. 1992 at Alert, a very high latitude site in the Canadian Arctic where very large bearing errors and systematic bearing swings, sometimes in excess of + or - 50 deg, are known to occur.
Author (revised)

N93-23617# Leicester Univ. (England). Dept. of Engineering.
BEARING DETERMINATION AND BEARING QUALITY INDICATION FROM A GONIOMETRIC HF DF SYSTEM
E. M. WARRINGTON and T. B. JONES *In* AGARD, Radiolocation Techniques 11 p (SEE N93-23598 08-32) Nov. 1992 Sponsored by Dept. of National Defence
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03
A computer based model of an automated wide aperture goniometric HF direction finder (type DF6) was developed to investigate the system performance under various simulated signal environments. Several test runs of the model indicated that the original DF6 algorithm could be modified to yield a significant improvement in the measured bearing accuracy and in addition provide a meaningful indication of the quality of the measured bearing. These modifications were implemented and tested at two sites in Canada. A system located in Ottawa was tasked against known transmissions from Halifax, Nova Scotia (950 km) and several hours of data collected. These measurements confirmed that the changes implemented as a result of the computer modeling produced improved bearing measurements. Further tests were conducted at Alert, a very high latitude site in the Canadian Arctic. At this site, the bearings often varied rapidly by several tens of degrees. These latter observations indicated that further changes to the DF algorithm should be made for systems deployed at this high latitude sight.
Author

N93-23618# Massachusetts Univ., Lowell, MA. Center for Atmospheric Research.
ANGLE OF ARRIVAL CHARACTERISTICS OF IONOSPHERIC SKYWAVE SIGNALS
D. MARK HAINES and BODO W. REINISCH *In* AGARD, Radiolocation Techniques 6 p (SEE N93-23598 08-32) Nov. 1992 Original contains color illustrations
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03
Skywave signals in the HF band experience a plethora of effects which distort them in the time, space, and spectral domains. The ability of a particular measurement to resolve discrete components which faithfully represent a single signal source (i.e., useful for angle-of-arrival estimation) is a somewhat random occurrence given any one fixed integration time. However, the fact that the signal components can be resolved in the spectral domain by our Doppler technique much of the time seems to indicate that there are indeed a finite number of discrete components in any sky wave signal and that the Doppler shift for each component varies independently such that they may be resolvable in the spectral domain.
Author (revised)

N93-23619# Centre National d'Etudes des Telecommunications, Lannion (France).
UTILIZATION OF A RECEPTION NETWORK OF THE LOSQUET ISLAND RETRODIFFUSION PROBE IN RADIOGONIOMETRY [UTLISATION DU RESEAU DE RECEPTION DU SONDEUR A RETRODIFFUSION DE L'ILE LOSQUET EN RADIOGONIOMETRIE]
J. Y. LESAOUT, F. GAUTHIER, N. RUELLE, and R. FLEURY *In* AGARD, Radiolocation Techniques 11 p (SEE N93-23598 08-32) Nov. 1992 In FRENCH
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03
The method of radiogoniometry from a single sensor operating from the Losquet Island retrodiffusion probe is described. The experimental results of the determination of the azimuth and the elevation of the waves having transitioned through the ionosphere, obtained by well-located emitters, are presented. The measured angles are compared to the results from a propagation model and to the arrival directions calculated by an oblique transposition of vertical ionograms. It is shown that the azimuth in which the emitter is found can be determined with a precision which is that of the accuracy of the measurement, and at elevation, the method allows the measurement of the angles associated with the dominant trajectories even if their performances are limited in the presence of multitrajectories.
Transl. by FLS

N93-23620# NAVSYS Corp., Colorado Springs, CO.
TEST RESULTS OF THE ADVANCED TRANSLATOR PROCESSING SYSTEM
ALISON K. BROWN, WILLIAM SWARD, and PETER BROWN *In* AGARD, Radiolocation Techniques 12 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03
The Advanced Translator Processing System was developed to provide a low cost alternative to tracking translated GPS signals. It is backwards compatible with the Translator Processing System (TPS) currently used to track Ballistic Missile Translators (BMT) by the US Ranges. NAVSYS has also developed a BMT compatible Translator. A key element of the ATPS is the Preamplifier/Downconvertor (P/DC) module which was developed by NAVSYS to condition the received Translator signal so it can be tracked with a conventional C/A code receiver. This significantly reduces the cost of the hardware by allowing the ATPS to be constructed mostly from off-the-shelf components. The ATPS and Translator were tested against the RAJPO Ballistic Missile and Translator Processing System Specifications. This paper presents the results of tests demonstrating the performance of the ATPS and Translator under different operating conditions. NAVSYS has also developed a Post Test Processing System (PTPS), incorporating the same components, which records the Translator data during the tests. When this data is played back, high-accuracy Time and Space Position <iformation (TSPI) data can be computed on the vehicle even under extreme dynamics.
Author

N93-23621# Shape Technical Center, The Hague (Netherlands). Communications Div.
COMMUNICATION INTERFERENCE/JAMMING AND PROPAGATION ANALYSIS SYSTEM AND ITS APPLICATION TO RADIO LOCATION
H. KUZUCU *In* AGARD, Radiolocation Techniques 14 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03
Modern defense systems depend on comprehensive surveillance capability. The ability to detect and locate the radio signals is a major element of a surveillance system. With the increasing need for more mobile surveillance systems in conjunction with the rapid deployment of forces and the advent of technology allowing more enhanced use of small aperture systems, tactical direction finding (DF) and radiolocation systems will have to be operated in diverse operational conditions. A quick assessment of the error levels expected and the evaluation of the reliability of the fixes on the targeted areas bears crucial importance to the effectiveness of the missions relying on DF data. This paper presents a sophisticated, graphics workstation based computer tool developed for the system level analysis of radio communication systems and describes its use in radiolocation applications for realizing such accurate and realistic assessments with substantial money and time savings.
Author

N93-23622# Alenia, Turin (Italy). Settore Sistemi Difesa.
AIRBORNE SYSTEM FOR DETECTION AND LOCATION OF RADIO INTERFERENCE SOURCES
BRUNO AUDONE and ALBERTO PASTORE *In* AGARD, Radiolocation Techniques 12 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03
The rapid expansion of telecommunication has practically saturated every band of Radio Frequency Spectrum; a similar expansion of electrical and electronic devices has affected all radio communications which are, in some way, influenced by a large amount of interferences, either intentionally or unintentionally produced. Operational consequences of these interferences, particularly in the frequency channels used for aeronautical services, can be extremely dangerous, making mandatory a tight

control of Electromagnetic Spectrum. The present paper analyzes the requirements and the problems related to the surveillance, for civil application, of the Electromagnetic Spectrum between 20 and 1000 MHz, with particular attention to the detection and location of radio interference sources; after a brief introduction and the indication of the advantages of an airborne versus ground installation, the airborne system designed by Alenia in cooperation with Italian Ministry of Post and Telecommunication, its practical implementation and the prototype installation on board of a small twin turboprop aircraft for experimentation purposes is presented. The results of the flight tests are also analyzed and discussed.
Author (revised)

N93-23623# Aerospatiale, Magny-Les-Hameaux (France). Service DE/ETRI.
LOCALIZATION SYSTEM BASED ON DATA MERGING OF IMAGES AND INERTIA
J. Y. CARTOUX, G. SELLA, L. AGRANIER, T. PECHOUX, and G. GRENIER *In* AGARD, Radiolocation Techniques 4 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A01/MF A03
The accuracy which is now required in the target approach of the modern missiles, requires the use of several sensors. Inertial systems, GPS when available, and imaging sensors are combined to improve the overall accuracy by the means of filtering and data merging techniques. Several tasks can be realized by the imaging system: targets detection and identification, missile position and motion estimation. The resulting information will be used as command parameters under certain conditions of robustness and accuracy. Our goal is not only to compute these parameters but to specify their domain of usability. Our approach is based on the development of a global simulator. The models of the inertial systems, the information computed by the imaging sensors are combined in a global Kalman filter scheme. The goal is to provide the user with the ability of studying the sensibility of the vision algorithms to some system parameters and external conditions in order to get the best overall accuracy. In the first part of this paper, we present the Kalman filter scheme and the issues involved. In the second chapter, the data that can be obtained from imaging techniques and the associated treatments are presented. We specify what are the constraints and the conditions under which these data can be obtained and study their sensibility to some system parameters. Author (revised)

N93-23624# Paris-Sud Univ., Orsay (France). Lab. d'Electronique et de Technologie de l'Informatique.
FRACTAL THEORY FOR LARGE LACUNAR ANTENNA ARRAYS [THEORIE FRACTALE DES GRANDS RESEAUX D'ANTENNES LACUNAIRES]
C. GOUTELARD *In* AGARD, Radiolocation Techniques 15 p (SEE N93-23598 08-32) Nov. 1992 In FRENCH
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03
The complexity of the arrays is directly tied to the number of antennas of which they are composed. The laws of radiation in the far field are well known and are inferred from the law of illumination of the antenna. The worry of the inventor is, as always, to determine, for a number of possible antennas, their spatial partition which assures the most advantageous law of radiation. The electronic orientation of the lobe of the antenna and the functioning within a wide band makes the problem more complex. The desire to obtain a lobe of narrow principal radiation and to limit the amplitude of secondary lobes is always contradictory. Regular structures used fix the characteristics of the diagrams of radiation in which the variations which obey the known laws are less favorable than the optimization of the diagrams. Aleatory structures can be used, but the correct results are not obtained until after multiple attempts, without which it is possible to be assured that the solution kept is the best. Fractal structures give results which one knows determine, a priori, the characteristics. Certain structures take particularly well to the construction of antennas and permit the best adjustment to finesse the principal lobe and remount the secondary lobes. Particular fractal themes permit the regulation of the problems of arrays in 1, 2 or 3 dimensional space. The fractal structures can be obtained by deterministic processes but also by the introduction of aleatory fluctuations around the deterministic model, which result in pseudo-aleatory fractal structures, or models built by totally aleatory processes which result in fractal aleatory models.
Transl. by FLS

N93-23625# Thomson-CSF, Gennevilliers (France). Div. RGS.
LOCATION OF EMISSIONS BY EVASION OF FREQUENCY AND GUSTS BY SEQUENTIAL ANALYSIS SENSOR IN FAST SCANNING [LOCALISATION D'EMISSIONS A EVASION DE FREQUENCE ET RAFALES PAR CAPTEUR A ANALYSE SEQUENTIELLE EN BALAYAGE RAPIDE]
D. JOSSET *In* AGARD, Radiolocation Techniques 6 p (SEE N93-23598 08-32) Nov. 1992 In FRENCH
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03
The use of techniques of transmission by evasion of frequency or gusts in VUHF in order to fight against conventional ECM systems is more and more widespread. The appearance of rapid goniometric sensors makes the interception and goniometry of these signals possible. The localization of these signals by a conventional system requires that the emission be set on standby. In order to avoid this problem, a system of extraction of the emissions with evasion of frequency and gusts with goniometry before localization is proposed, this being carried out on 'synthetic' emissions calculated from goniometric detections. The calculation of these 'synthetic' emissions requires an algorithm allowing the reconnaissance and the identification of the types of emissions. Beginning with the reconnaissance carried out on several goniometers, emitters are sought which have the same characteristics on the various sensors before carrying out localization by the Cartesian least squares method.
Transl. by FLS

N93-23626# Lockheed Sanders, Inc., Nashua, NH.
RADIO LOCATION THROUGH HIGH RESOLUTION EIGENSTRUCTURE PROCESSING TECHNIQUES THAT YIELD ACCURATE MULTIPATH AOA AND DIFFERENTIAL TIME DELAY ESTIMATES
LEON M. LEWANDOWSKI and KEITH A. STRUCKMAN *In* AGARD, Radiolocation Techniques 5 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A01/MF A03
An eigenstructure based, doubly adaptive array processing algorithm is described. This algorithm resolves the differential time of arrival (DTOA) between the direct signal and a delayed replica that arrives over a different ray path. Simulations, using theoretical responses of a circular eight element dipole array, illustrate the resolving characteristics of the algorithm. Author

N93-23627# Middle East Technical Univ., Ankara (Turkey). Dept. of Electrical and Electronic Engineering.
MULTIPLE EMITTER DIRECTION FINDING FROM A CIRCULAR ARRAY BY SINGLE SNAPSHOT PROCESSING
Y. TANIK and A. KOC *In* AGARD, Radiolocation Techniques 8 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03
In this work, a new algorithm for multiple emitter direction finding for circular arrays is proposed. The algorithm uses a single snapshot for processing. The observation is first transformed into frequency domain. Then, by using the Fourier series coefficients of pattern of the sensors, it is transformed into a suitable sequence. The linear prediction method is applied to the resulting sequence to determine the direction of arrivals from the zeros of corresponding linear prediction filter. An iterative correction scheme is used to improve the accuracy of the estimates. Computer simulations have been performed to evaluate the performance of the algorithm. It has been observed that the algorithm operates successfully if the array circumference is comparable to the wavelength. Author

N93-23628# Aerospatiale, Magny-Les-Hameaux (France). Service E/ETRI.
AUTOMATIC FEATURE EXTRACTION AND LOCALIZATION USING DATA FUSION OF RADAR AND INFRARED IMAGES
STEPHANE HOUZELLE and GERARD GIRAUDON (Institut National de Recherche d'Informatique et d'Automatique, Valbonne, France.) *In* AGARD, Radiolocation Techniques 9 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03
This paper presents two examples of low level strategies using multi sensor data fusion, one for bridge extraction, and one for urban area extraction. These extractions are made from a

couple of coregistered Synthetic Aperture Radar (SAR) and SPOT images. These features are very different by their dimensions, their shape, and their radiometry. Thus we can prove the reliability of our approach on various types of features. Our method uses the notion of complementarity of each sensor, and the notion of context in the observed scene. For bridge detection, we first segment water in the SPOT image, to spatially constrain the bridge research in the SAR image. This research is achieved using a correlation method. To detect an urban area, we first use the knowledge that it produces very bright texture in SAR imagery. Thus, the main part of urban backscatters is extracted using an adaptative thresholding which keeps the upper band of the gray level histogram of the SAR image. This mask is then used for classification as a training mask of urban area texture in SPOT image. We determine the non urban zone training set using a distance map of the urban training zone boundaries. Classification is performed with a multivariate Gaussian classifier. The results we obtained are very encouraging, especially if we consider the robustness of the bridge detection method. Author

N93-23629# Alcatel Espace, Toulouse (France). Ground Systems Dept.

DIGITAL PROCESSING FOR POSITIONING WITH ONE SATELLITE

A. MARGUINAUD *In* AGARD, Radiolocation Techniques 12 p (SEE N93-23598 08-32) Nov. 1992
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03

This paper is a product of theoretical and practical work done with geostationary and low earth-orbiting (SARSAT) satellites. Reliability, efficiency and cost considerations have resulted in an all digital implementation with standard processors. The analog signal is represented by complex samples calculated from real sampling with an algorithm based on an original concept. Any telecommunication (or radar) signal is represented by reversible transformations of a sinusoidal carrier. Maximum likelihood synchronization and demodulation must be used and consists of reconstructing the 'best' carrier from the received signal. Depending on the uncertainty level, one tries a certain number of time-frequency hypotheses, and for each hypothesis, one makes optimum estimations of 3 carrier parameters: modulus, phase and frequency. Since one deals with one circular function, it is straightforward to develop the phase, so that phase and frequency are the 2 parameters defining a straight line in the developed phase-time plane. The 2 corresponding estimators are decorrelated. For a terrestrial vehicle, one can have a good estimation of its velocity, and even for a stationary satellite there is an apparent periodical known motion, which can be used to locate the vehicle by a convenient combination of elementary estimations. Of course some frequency spreading, clock stability and delay are necessary, but explicit performance is easy to derive as functions of operational conditions. Analysis of numerical results may suggest useful practical systems. Author

N93-23630# Kings Coll., London (England). Dept. of Physics.

RADIOLOCATION IN THE LOWER ELF FREQUENCY BAND

C. P. BURKE and D. LLANWYN JONES *In* AGARD, Radiolocation Techniques 9 p (SEE N93-23598 08-32) Nov. 1992
(Contract(s)/Grant(s): SERC-SG/D/10351)
(AGARD-CP-528) Copyright Avail: CASI HC A02/MF A03

A system for recording Extremely Low Frequency (ELF) noise bursts produced by global lightning activity is described. The location of the source lightning flashes for some 320 such events has been deduced from these data. The range of the sources was found by modelling the data using a least-squares fit to the complex wave impedance obtained from the standard propagation theory applicable to the Earth-ionosphere spherical-shell waveguide. The source bearings were deduced from two orthogonal components of the magnetic field vector using the usual goniometric technique. The source range and bearing serve to locate each source on the surface of the Earth. The data show that the majority of ELF event sources are located in tropical regions, an average of 7.4 Mm away from the observing station situated at 51.14 degrees North, 1.44 degrees West (Geographic). The use of such a system to monitor worldwide thunderstorm activity, so far as this relates to ELF events has been demonstrated. Author

N93-23631# Paris-Sud Univ., Orsay (France). Lab. d'Etude des Transmissions Ionospheriques.

THE WG SEQUENCES: QUASI PERFECT BINARY SEQUENCES [LES SEQUENCES WG: SEQUENCES BINAIRES QUASI PARFAITES]

C. GOUTELARD *In* AGARD, Radiolocation Techniques 19 p (SEE N93-23598 08-32) Nov. 1992 In FRENCH
(AGARD-CP-528) Copyright Avail: CASI HC A03/MF A03

The research of sequences presenting good periodic correlation functions is a subject on which much research has been focussed over a long time. The binary sequences are of particular interest because of their simplicity of generation and of treatment. The W.G. (Wolfmann-Goutelard) sequences presented in this report possess quasi perfect periodic correlation functions, such that outside of the central pic, these functions are null except at one point. It is shown therefore that the structure of W.G. sequences is unique and that it is the result of the interlacing of three periodic sequences. The properties of these sequences are studied and it is shown that the algorithms of determination reduce the complexity of their research. The conditions for the existence, or nonexistence, of these sequences are given and the existing sequences for the lengths N = 8 alpha + 4, N = 16 alpha + 4, and N = 32 alpha + 4 where alpha belongs to Z are given up to N = 20000. Author

N93-29892# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.

T(LC2)ACS(LC3)ATS FOR SURVEILLANCE VERIFICATION AND C3I [LES SATELLITES TACTIQUES (TACSATS) POUR LA SURVEILLANCE, LA VERIFICATION ET LA C3I]

Feb. 1993 252 p Symposium held in Brussels, Belgium, 19-22 Oct. 1992
(AGARD-CP-522; ISBN-92-835-0700-2; AD-A264371) Copyright Avail: CASI HC A12/MF A03

The symposium dealt with small satellites used for tactical applications that might be of value to NATO. The 11 sessions covered TacSat concepts and needs, aspects of TacSat applications, TacSat system applications, communication concepts, launch systems, spacecraft bus, advanced technology, radar concepts, electro-optics concepts, and two panel discussions. The information generated by the symposium will be used by Working Group 16 to report on the utility of such satellites and applications to meet future NATO needs. For individual titles, see N93-29893 through N93-29913.

N93-29895# MATRA Marconi Space Portsmouth, Hampshire (England).

TACSAT GROUND CONTROL AND DATA COLLECTION

C. G. COCHRANE *In* AGARD, TacSats for Surveillance Verification and C3I 6 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

This paper addresses the concept of a satellite based system serving the needs of tactical users for direct access to communications and various forms of surveillance. Such a system must take account of the most effective methods for deployment and maintenance during its intended period of operation. In terms of the mission needs, the Tactical Satellite System (TACSAT) is required to provide the services for tactical users over a relatively small region of maybe some 1000-2000 km diameter. Also, the concept is likely to involve relatively short periods of operation of about 3 to 6 months for a typical operation scenario. The paper, therefore, addresses a system concept in which the emphasis is placed on reducing the scale of the logistics involved in the deployment of TACSAT elements and simplifying the ground operations and facilities necessary for the users to gain access to the services provided. This paper addresses the following: (1) the need for 'launch on demand'; (2) the possibility of launches being directly under the control of the area commander; (3) operating concepts for TACSATs, comparing the approach of launch-via-residual-mass as part of a larger mission, not dedicated to the TACSAT mission with the approach of dedicated, launch-on-demand; (4) identification of information flow requirements for TACSAT integrity and status evaluation and for surveillance data recovery; (5) determination of technical and cost drivers influencing the form and cost of ground installation and logistic issues; (6) integration of TACSAT facilities and services with other communications and surveillance systems available to the Tactical Commander; and (7) investigation of techniques

minimize the ground control and data collection overhead. Author (revised)

N93-29899# Marmara Research Inst., Gebze (Turkey).
CONSIDERATIONS FOR NATO SATELLITE COMMUNICATIONS IN THE POST-2000 ERA
A. NEJAT INCE *In* AGARD, TacSats for Surveillance Verification and C3I 8 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

The National Delegates Board of AGARD, upon recommendation by the Avionics Panel of AGARD, approved in March 1986 the establishment of WG-13 to study satellite communications for NATO under the direction of Prof. Dr. Nejat Ince of Turkey. Some 14 scientists/engineers, from research and industrial establishments of Canada, France, the Federal Republic of Germany, Norway, Turkey, the United Kingdom, the United States of America as well as from International Military Staff of NATO and SHAPE Technical Centre, participated in the work of WG-13. This paper is a brief summary of the studies carried out by the group in the period 1988-1990 on the type of satellite communication systems which NATO can have in the post-2000 era including the critical techniques and technologies that need to be developed for this purpose. Derived from text

N93-29900# Massachusetts Inst. of Tech., Lexington, MA. Lincoln Lab.
ADVANCED TECHNOLOGIES FOR LIGHTWEIGHT EHF TACTICAL COMMUNICATIONS SATELLITES
DAVID R. MCELROY, DEAN P. KOLBA, WILLIAM L. GREENBERG, and MARILYN SEMPRUCCI *In* AGARD, TacSats for Surveillance Verification and C3I 9 p (SEE N93-29892 11-32) Feb. 1993
(Contract(s)/Grant(s): F19628-90-C-0002)
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

The communications capabilities provided by EHF satellites can range from low data rate services (75 to 2400 bps per channel) to medium data rate links (4.8 kbps to 1.544 Mbps per link) depending on the payload configuration. Through the use of EHF waveform standards, the EHF payloads will be compatible with existing and planned EHF terminals. Advanced technologies permit the development of highly capable, lightweight payloads which can be utilized in a variety of roles. The key payload technologies include adaptive uplink antennas; high speed, low power digital signal processing subsystems; lightweight frequency hopping synthesizers; and efficient solid-state transmitters. The focus in this paper is on the signal processing and frequency generation technologies and their application in a lightweight EHF payload for tactical applications. Author

N93-29901# MPR Teltech Ltd., Ottawa (Ontario).
SYNCHRONIZATION TECHNIQUES FOR MEDIUM DATA RATE EHF MILSATCOM SYSTEMS
G. BOUDREAU and M. SCHEFTER *In* AGARD, TacSats for Surveillance Verification and C3I 9 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

In the area of MILSATCOM, considerable effort is currently being expended on the development of systems operating in the EHF frequency bands and employing onboard processing. Two of the principal advantages of employing these features are that the MILSATCOM system will be capable of increased throughput and will possess increased immunity to jamming and other channel impairments. Most of the previous research and development in EHF MILSATCOM has concentrated on Low Data Rate (LDR) waveforms, for data rates up to 2.4 kbps. In order to meet the requirements for increased throughput, Medium Data Rate (MDR) waveforms are being developed. These systems include data rates up to and including T1. This paper examines the constraints that communicating at MDR data rates places on synchronization and provides an overview of some of the various techniques and algorithms that can be employed for both spatial and time acquisition as well as tracking. Both channel and equipment impairments affecting synchronization are examined. Robust open and closed loop acquisition and tracking algorithms are examined in conjunction with onboard processing techniques. Performance is discussed in terms of SNR, acquisition time, probability of correct acquisition and probability of false acquisition. Tradeoffs in a MILSATCOM system design based on various user requirements are also presented. Author

N93-29902# Microtel Pacific Research Ltd., Burnaby (British Columbia).
TERRAIN AND COVERAGE PREDICTION ANALYSES FOR NON-GEOSTATIONARY ORBIT EHF SATELLITE COMMUNICATIONS
M. JAMIL AHMED *In* AGARD, TacSats for Surveillance Verification and C3I 11 p (SEE N93-29892 11-32) Feb. 1993
(AGARD-CP-522) Copyright Avail: CASI HC A03/MF A03

This paper examines communications coverage from five non-geostationary satellite orbits. These orbits are as follows: circular inclined synchronous; GPS; Molniya 12 and 24 hour; and Tundra orbits. It also shows the increase in propagation loss due to irregular terrain and the foliage loss at mm waves, as well as the combined effect of terrain and foliage on satellite view duration. It is concluded that coverage calculations for EHF satcom earth terminals need to take into account terrain and foliage losses. Author (revised)

N93-30727# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
ELF/VLF/LF RADIO PROPAGATION AND SYSTEMS ASPECTS [LA PROPAGATION DES ONDES RADIO ELF/VLF/LF ET LES ASPECTS SYSTEMES]
May 1993 343 p Symposium held in Brussels, Belgium, 28 Sep. - 2 Oct. 1992
(AGARD-CP-529; ISBN-92-835-0712-6; AD-A267991) Copyright Avail: CASI HC A15/MF A03

This publication reports the papers presented to a specialists' meeting held by the Electromagnetic Wave Propagation Panel at its Fall 1992 meeting. The topics covered on the occasion of that symposium include the following: (1) propagation aspects--numerical modelling, propagation measurements, and propagation in sea water; (2) radio noise and interference--long wave TE/TM noise prediction model, measurements, and ELF generated by auroral electrojet modulation; (3) antenna considerations--antenna fundamentals, scale modelling, measurements of pattern and bandwidth, and tethered aerostat VLF/LF transmitting antennas; (4) System aspects--viability assessment for reliable LW communication links; and (5) future satellite systems--orbiting system for ELF/VLF strategic communications, and tethered satellite systems. For individual titles, see N93-30728 through N93-30755.

N93-30728# Communications Research Centre, Ottawa (Ontario).
INTRODUCTION
JOHN S. BELROSE *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 12 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

An introduction and welcome to the Specialists' Meeting on 'ELF/VLF/LF Radio Propagation and System Aspects' given at the Electromagnetic Wave Propagation Panel Symposium, held at the Quartier Reine Elisabeth, Brussels, Belgium, 28 Sep. - 2 Oct. 1992, is presented. The following topics are discussed: the early history of radio communications, NATO interest in ELF/VLF/LF, propagation mode, effect of the finite conductivity of the ground, and VLF antennas. CASI

N93-30729# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
NUMERICAL MODELING OF THE PROPAGATION MEDIUM AT VLF/LF
J. A. FERGUSON *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 9 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03

A reliable knowledge of radio signal amplitude and phase characteristics is required to design and maintain communications and navigational circuits at VLF and LF. The ability to accurately calculate signal levels as a function of frequency, position, and time is of considerable importance in achieving reliable assessment of communication and navigation coverage. Detailed computer models based on multiple mode waveguide theory were developed. These models were found to produce good comparisons between measurements and calculations of signal variations as a function of propagation distance. However, results can be very sensitive to the ionospheric inputs to these computer models. This paper

presents an overview of the computer model and results of empirical modeling of the propagation medium. Author (revised)

N93-30730# Naval Undersea Warfare Center, New London, CT.
ELF PROPAGATION HIGHLIGHTS
PETER R. BANNISTER *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 15 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

In this paper, we have presented a tutorial overview of ELF propagation. We have also compared the Greifingers simple form approximate expressions (which relate ELF propagation constants to realistic ionospheric conductivity profiles) with experimentally derived results for both daytime and nighttime ambient propagation conditions. The inverse problem has also been considered. We have used the experimentally determined values of effective attenuation rate and excitation factor, along with the modified Greifinger equations, to establish representative ionospheric parameters for each propagation path considered. These parameters include the reflection height h(sub o), the inverse scale height Beta (which is equal to 1/Zeta(sub 0)), and the reference height H of the equivalent exponential ionospheric conductivity profile. We have recently analyzed some of the field strength data taken at the U.S. Navy's four land based ELF monitoring sites (New London, CT; Norfolk, VA; Kings Bay, GA; and Pearl City, HI). Both the daytime and nighttime inferred values of excitation factors and daytime attenuation rates are in good agreement with previous 75 Hz band measurements taken over various propagation paths. However, the summertime nighttime attenuation rates are substantially lower (approximately 0.6 dB/Mm compared to approximately 1.0 dB/Mm). Also, the summertime daytime attenuation rates (approximately 1.25 dB/Mm) are lower than measured during other times of the year (approximately 1.50 dB/Mm). Author (revised)

N93-30731*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE CONE STRUCTURE AND FOCUSING OF THE ELECTRIC FIELD OF VLF AND LF WAVES AT HIGH ALTITUDES OF THE IONOSPHERE
Y. L. ALPERT (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.) and J. L. GREEN *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 11 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

This paper presents a short review of the frequency and angle dependencies of the electric field radiated by an electric dipole E = E(sub 0)cos(omega)t in a magnetoplasma and detailed results of numerical calculations of (E) in the VLF and LF frequency bands 0.02f(sub b) is less than or equal to F is less than or equal to 0.5f(sub b) in the ionosphere and magnetosphere in the altitude region Z = (800 - 6000) km (F is approximately (4 - 500) kHz and f(sub b) is approximately equal to (1.1 to 0.2) MHz is the electron gyro-frequency). The amplitudes of the electric field have large maxima in four regions: close to the direction of the Earth magnetic field line B(sub 0) (it is the so called Axis field E(sub 0); in the Storey E(sub St); Reversed Storey E(sub RevSt); and Resonance E(sub Res) Cones. The maximal values of E(sub 0), E(sub Res), and E(sub Rev ST) are the most pronounced close to the low hybrid frequency, F is approximately F(sub L). The flux of the electric field is concentrated in very narrow regions, with the apexes angles of the cones delta(beta) is approximately (0.1 - 1) degree. The enhancement and focusing of the electric field increases with altitude starting at Z is greater than 800 km. At Z is greater than or equal to 1000 up to 6000 km, the relative value of E, in comparison with its value at Z equals 800 km is about (10(exp 2) to 10(exp 10)) times larger. Thus, the flux of VLF and LF electromagnetic waves in the Earth magnetoplasma produces and is guided by very narrow pencil beams, similar, let us say, to laser beams. Author (revised)

N93-30732# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
VLF/LF PROPAGATION MEASUREMENTS
JOHN E. BICKEL *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 14 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

The Research, Development, Test, and Evaluation (RDT&E) division of the Naval Command, Control and Ocean Surveillance Center (NCCOSC), and its predecessors, Navy Electronics Laboratory (NEL), Naval Electronics Laboratory Center (NELC), and Naval Ocean Systems Center (NOSC), have had a continuing program to develop a reliable VLF/LF communications coverage prediction capability for the U.S. Navy. This involves the measurement of field intensity of many communication stations, the development of propagation models to fit the data measured, and the validation of these models to verify predictions for all seasons world-wide, including possible solar cycle effects. During the current campaigns, data were recorded using various platforms including numerous aircraft, six ships, three submarines, and up to 28 fixed sites since 1981. Currently, data are being recorded aboard two ships and at seven fixed sites. An attempt is made to maintain an overall root-mean-square (rms) accuracy of 0.5 dB, with system calibration and stability measured to the order of 0.1 dB ring. The goal for the model under development is to fit these data and extrapolate predictions to other propagation conditions to within 1 dB. This was a challenging task where local environmental effects can cause significantly larger perturbations. A review of the literature is presented summarizing and comparing methods and techniques used by other researchers in the field. This is followed by discussion of the commercial equipment used, the calibration and recording procedures followed, a comparison of results obtained simultaneously using various platforms and sites, and an estimate of the overall accuracy/reliability of the data obtained. Author (revised)

N93-30733# Communications Research Centre, Ottawa (Ontario).
VLF PROPAGATION MEASUREMENTS IN THE CANADIAN ARCTIC
WILFRED R. LAUBER and JEAN M. BERTRAND *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 12 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

For the past three years, during a period of high sun spot numbers, propagation measurements were made on the reception of VLF signals in the Canadian Arctic. Between Aug. and Dec. 1989, the received signal strengths were measured on the Canadian Coast Guard icebreaker, John A. MacDonald in the Eastern Canadian Arctic. Between Jul. 1991 and Jun. 1992, the received signal strengths were measured at Nanisivik, Baffin Island. The purposes of this work were to check the accuracy and estimate variances of the Naval Ocean Systems Center's (NOSC) Long Wave Propagation Capability (LWPC) predictions in the Canadian Arctic and to gather ionospheric storm data. In addition, the NOSC data taken at Fort Smith and our data at Nanisivik were used to test the newly developed Longwave Noise Prediction (LNP) program and the CCIR noise predictions, at 21.4 and 24.0 kHz. The results of the work presented and discussed in this paper show that in general the LWPC predicts accurate values of received signal strength in the Canadian Arctic with standard deviations of 1 to 2 dB over several months. Ionospheric storms can gauge the received signal strengths to decrease some 10 dB for a period of several hours or days. However, the effects of these storms are highly dependent on the propagation path. Finally the new LNP atmospheric noise model predicts lower values of noise in the Arctic than the CCIR model and our limited measurements tend to support these lower values. Author (revised)

N93-30734# Telefunken System Technik G.m.b.H., Ulm (Germany). Radio Communications Subdivision.
THEORETICAL AND EXPERIMENTAL COVERAGE ANALYSIS OF A VLF TRANSMITTER
DETLEV BORGMANN *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 5 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A01/MF A03

The coverage area of a VLF transmitting station, located in the northern part of Germany, is analyzed. In order to predict the

receiving skin depth for the complete operation area of the VLF station, some investigations were made in theoretical propagation models. Then a computer program based on the wave guide mode theory was implemented. To verify the validation of the theoretical model, measurements of field strength in some specific areas were carried out. The first part of the paper is concerned with a description of the theoretical approach of the coverage analysis. The second part describes some properties of the operation area and gives in detail results from measurements. Finally, a comparison of theoretical and measured data then shows the quality of agreement between theory and praxis.
Author (revised)

N93-30735# IWG Corp., San Diego, CA.
INVESTIGATIONS OF EQUATORIAL IONOSPHERE NIGHTTIME MODE CONVERSION AT VLF
VERNE HILDEBRAND *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 11 p (SEE N93-30727 11-32) May 1993 Sponsored in part by ONR
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03
VLF Radiowave propagation provides one of the few viable tools for exploring the properties of the lower D-region ionosphere. Conversely, VLF communications coverage analysis and prediction is directly dependent on the quality of models for the D-region ionosphere. The VLF Omega navigation signals are an excellent and under-utilized resource for conducting D-region research in direct support of VLF communications. Stations are well placed for investigating polar, mid latitude, and equatorial phenomena. Much can be learned by fully utilizing the very stable signals radiated at five frequencies, available from each of the eight transmitters, and taking full advantage of modal structure. While the Omega signals, 10.2 to 13.6 kHz, are well below the VLF communications band, we contend that much of the knowledge gained on D-region characteristics can be directly applied at the higher frequencies. The opportunity offered by Omega needs to be exploited. With the Global Positioning System (GPS) coming onboard as the prime means for global navigation, pressure is mounting to phase out Omega. In this paper we describe how we are using Omega along with computer codes of full wave VLF propagation, provided to us by the U.S. Naval Ocean Systems Center (NOSC), for ionosphere research and by example illustrate the potential for other investigations. Author (revised)

N93-30736# British Antarctic Survey, Cambridge (England).
TRANSIENT (APPROXIMATELY EQUALS 10 S) VLF AMPLITUDE AND PHASE PERTURBATIONS DUE TO LIGHTNING-INDUCED ELECTRON PRECIPITATION INTO THE IONOSPHERE (THE TRIMPI EFFECT)
A. J. SMITH, P. D. COTTON, and J. S. ROBERTSON *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 7 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03
This paper describes certain characteristics and statistics of the Trimpi effect, as observed near to and equatorward of the Antarctic Peninsula region, inferred using data from specially designed narrowband OPAL (Omega Phase and Amplitude Logger) receivers deployed in 1989 at Faraday and Halley stations, Antarctica. The amplitude and phase of signals from four Omega VLF transmitters were recorded in each Omega segment (8 segments per 10 s). A 12 month data set was scanned for Trimpi events which, however, were observed on only three of the eight paths, namely Hawaii-Faraday, Argentina-Faraday, and Argentina-Halley, due to inadequate signal-noise ratio on the other paths. The great majority of the approximately 3500 observed events occurred at night. For the all-sea, Hawaii-Faraday path at night, with a single mode dominant at the receiver, lightning-induced electron precipitation (LEP) was inferred to be occurring up to approximately 1.8 Mm from Faraday. A scatter plot of Trimpi amplitude versus phase for this path is interpreted to infer that LEP regions responsible for the events occurred mostly in the L-range 2-3, with the horizontal size of an affected region in the ionosphere being typically 50 km latitudinally and 200 km longitudinally. Author (revised)

N93-30737*# Stanford Univ., CA. Space, Telecommunications and Radioscience Lab.
LIGHTNING-INDUCED EFFECTS ON VLF/LF RADIO PROPAGATION
U. S. INAN and J. V. RODRIGUEZ *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 10 p (SEE N93-30727 11-32) May 1993 Sponsored by NASA, Washington
(Contract(s)/Grant(s): N00014-82-K-0489; N00014-92-J-1579; NSF DPP-90-20687; NSF ATM-91-13012)
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03
In recent years, at least two different ways in which energy from lightning discharges couples into the lower ionosphere and the radiation belts have come to the fore. In this paper, we briefly review these recent results especially from the point of view of their effects on VLF/LF radio propagation in the earth-ionosphere wave guide. We separately discuss two different mechanisms of coupling, namely lightning-induced electron precipitation, and lightning-induced heating and ionization of the lower ionosphere. We also discuss a planned active VLF wave-injection experiment designed to investigate ionospheric heating by VLF waves under controlled conditions and to generate ELF waves by modulated VLF heating. Author (revised)

N93-30738# Leicester Univ. (England). Dept. of Engineering.
STUDIES OF THE PROPAGATION OF LOW FREQUENCY (LF) RADIO WAVES
E. M. WARRINGTON and T. B. JONES *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 20 p (SEE N93-30727 11-32) May 1993 Sponsored in part by Defence Research Agency
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03
Low frequency (30-300 kHz) radio waves can propagate to great distances with little attenuation in the cavity formed by the earth and the ionosphere. Because of the relatively high frequency at LF, many active propagation modes can occur between the transmitter and receiver. Changes in the ionospheric conductivity or reflection height can influence the phase and amplitude of these modes and, hence, produce mutual interference. Because of these interference effects, the propagation is less stable than at VLF and the received field strength becomes more difficult to predict. In the present investigation, the WAVEHOP program was employed in conjunction with a range of ionospheric models to estimate the receiver field strength over a number of experimental paths. The predicted values were compared with those measured in an attempt to validate the ionospheric models and the method of calculation. Author (revised)

N93-30739# Kings Coll., London (England). Dept. of Physics.
ELF PROPAGATION IN DEEP AND SHALLOW SEA WATER
C. P. BURKE and D. LLANWYNJONES *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 8 p (SEE N93-30727 11-32) May 1993 Sponsored in part by Defence Research Agency
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03
In this paper, electromagnetic wave propagation at Extremely Low Frequencies (ELF) in deep and shallow sea water is considered. The term 'ELF' is used here somewhat loosely to refer to the frequency band 0-3 kHz. The radiation source is considered to be located in the sea water and is taken to be a horizontal electric dipole (HED) or a vertical electric dipole (VED). For the deep water ease, a comparison is made between results computed using complex image theory and results calculated using the full Sommerfeld integral formulation. Both of these formulations include the lateral waves which propagate along the air-sea interface. Moving on to the case of shallow water, there are two lateral wave modes of propagation-lateral waves which propagate on the sea surface and along the seabed. These modes are included by numerical evaluation of the Sommerfeld integrals which appear in the complete solution. We also compare the relative efficacy of subsurface horizontal electric dipoles and vertical electric dipoles as radiators. For the case of zero frequency (dc), the Sommerfeld integrals simplify considerably enabling the fields to be evaluated as the sums of infinite series. This dc formulation leads to much reduced computation time. Finally, the effects on propagation of long-wavelength water gravity waves or tides on the surface of the sea are examined by considering these waves as a perturbation to the sea-air interface. Author (revised)

N93-30740# Vrije Univ., Brussels (Belgium).
COMPARATIVE STUDY OF UNDERSEA FIELDS PRODUCED BY VARIOUS DIPOLES
G. ANNAERT and A. BAREL *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 9 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03

ELF/VLF/LF-radiation by electric or magnetic dipoles located above or on the surface of the earth or sea is investigated from the exact Sommerfeld potentials. Due to the nonzero conductivity of the ground or sea water, the waves are strongly attenuated and only a small near field can be effectively used for communication in a low frequency range. The Fresnel coefficient approximation technique, which presumes a planar plane wave propagation, is correct in the far-field but loses great accuracy in a region close to the radiator. It is the purpose of this paper to review the electromagnetic propagation in layered media based on the rigorous spectral domain method. This theory expresses the Hertz potentials, either of the magnetic type A or the electric type F, in terms of Sommerfeld integrals. A communication range, as the maximum depth at which satisfactory signal reception is still possible, is derived in function of ground parameters, frequency, and dipole orientation. Author (revised)

N93-30741# Defence Research Agency, London (England).
A METHODOLOGY AND TOOL FOR THE PREDICTION OF DEPTH OF RECEPTION IN THE SEA FOR A VLF/LF COMMUNICATIONS SYSTEM
D. M. NICHOLLS *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 12 p (SEE N93-30727 11-32) May 1993 Sponsored in part by Ministry of Defence
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

This paper describes a method of predicting the depth performance of a VLF/LF (Very Low Frequency/Low Frequency) communications system for submarine reception. The method uses a Long Wave Propagation Capability program which includes parameters of the system to be considered, such as transmitter power, aerial, and receiver sensitivities. Results from an analysis for a particular communications system are presented including an audio visual format to show the expected variations in depth performance with reference to operational frequency, transmitter power, time of day and year, and the signal to noise requirements for the system. The analysis method is flexible and could be adapted for similar communications systems. Author (revised)

N93-30742# Pacific-Sierra Research Corp., Santa Monica, CA.
A LONG WAVE TE/TM NOISE PREDICTION MODEL
C. R. WARBER and E. C. FIELD, JR. *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 12 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

A computer model that predicts both horizontally and vertically polarized noise in the ELF to LF band (10 Hz-60 kHz) is described. Since naturally occurring radio noise in this band is produced by lightning, and propagates to the receiver via the earth-ionosphere waveguide, the model starts with average lightning flash density data which it turns into radiated power for horizontal and vertical noise. Adjustments are made to the radiated power to account for seasonal and latitudinal differences in the lightning processes. The noise power is then integrated over fairly large geographic areas into horizontal and vertical equivalent noise transmitters. The power radiated from each of these transmitters is propagated to the receiver location using standard anisotropic long wave propagation algorithms and well-known models of the earth-ionosphere waveguide. From the received power, the model predicts RMS noise, standard deviation, voltage deviation VD, and the amplitude probability distribution of the noise for both polarizations. Since the model is based on theory, it can also predict these parameters under disturbed ionospheric conditions. The model's agreement with data is demonstrated.
Author (revised)

N93-30743# Genoa Univ., Genoa (Italy). Dept. of Biophysical and Electronic Engineering.
APPLICATION OF NON-STANDARD SIGNAL PROCESSING TO ELF NOISE CHARACTERIZATION FOR THE TSS1-OESEE PROGRAMME
G. TACCONI, A. TIANO (Pavia Univ., Italy.), and S. PAGNAN (Consiglio Nazionale delle Ricerche, Genoa, Italy.) *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 8 p (SEE N93-30727 11-32) May 1993 Sponsored in part by Italian Space Agency
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03

Within the framework of the TSS1 (Tethered Satellite System)-Project, a measurement program on the electromagnetic background noise was performed. This program, called OESEE (Observation on the Earth Surface of Electromagnetic Emissions), intends to carry out a number of passive detections of possible emissions by the orbiting tethered system. From theoretical considerations on the cold plasma theory in the ionosphere, the expected frequency band of these emissions should be in the order of about 1 Hz up to 60 Hz. In order to design an optimal receiver of such a signal, the noise statistical characteristics have to be taken into account. From the literature, it was shown that this noise is characterized, from the statistical viewpoint, by a non-gaussian and non-stationary behavior. This paper outlines some recently proposed applications of non-gaussian and non-stationary signal processing techniques which can be usefully applied to ELF (Extremely Low Frequency) electromagnetic noise characterization for detection and parameter estimation purposes. Some simulation examples are presented together with some results obtained from experimental data of natural background noise in the ELF range recorded at Canary Islands as a preliminary test of the TSS1 mission. The TSS1 (Tethered Satellite System) is a NASA/ASI (Agenzia Spaziale Italiana) research project.
Author (revised)

N93-30744# Stanford Univ., CA. Space, Telecommunications and Radioscience Lab.
ELF/VLF RADIO NOISE MEASUREMENTS AT HIGH LATITUDES DURING SOLAR PARTICLE EVENTS
A. C. FRASER-SMITH and J. P. TURTLE (Rome Lab., Hanscom AFB, MA.) *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 8 p (SEE N93-30727 11-32) May 1993
(Contract(s)/Grant(s): F19628-89-K-0015; N00014-81-K-0382; N00014-90-J-1080; N00014-92-J-1576; NSF ATM-88-22560; NSF DPP-87-20167; NSF DPP-91-19552)
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03

We report simultaneous measurements of ELF/VLF radio noise (10 Hz-32 kHz) at three high latitude locations (Thule and Sondrestromfjord, Greenland; and Arrival Heights, Antarctica) during a number of moderately large and large solar particle events (SPE's) including some of the largest that have been observed during the last three decades. Thule is close to the center of the northern polar cap and thus the ELF/VLF noise signals reaching it are particularly exposed to the ionospheric effects of the SPE's, whereas the ELF/VLF noise signals at Sondrestromfjord and Arrival Heights, which are located closer to their corresponding auroral zones, should be less affected. These general expectations are supported by the results of our measurements, which show major changes occurring in the Thule noise statistics following the start of the polar cap absorption (PCA) caused by the SPE's and smaller changes at Sondrestromfjord and Arrival Heights. The changes depend markedly on the frequency of the noise signals. At Thule, for frequencies in the approximate range 250 Hz to 1.5 kHz, the diurnal variation in the ring noise amplitudes is typically suppressed during the 2-3 days following the start of the PCA, and in most of the examples we have examined there tends to be a decrease in the average amplitude. Nevertheless, increases can occur. Following the event of 12 Aug. 1989, the noise amplitudes increased by as much as 10-15 dB. For most other frequencies in the range 10 Hz-32 kHz there is little change in the noise statistics. However, in the range 3-10 kHz there tends to be a marked decline in the ring noise amplitudes at Thule in the 24 hours following the start of the PCA, after which there is a rapid recovery to the undisturbed levels. At Sondrestromfjord and, to a lesser extent, at Arrival Heights, the most marked change appears to be the suppression of the diurnal variation noise peaks and thus

lower average noise amplitudes in the 2-3 days following the start of the PCA. Author (revised)

N93-30745# Institute for Telecommunication Sciences, Boulder, CO.
ELF/VLF SPECTRUM MEASUREMENTS
M. G. LAFLIN *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 12 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03
A 16-bit digital spectrum analysis system was designed and built to provide measurement capabilities not currently available in commercial systems. The system provides the wide dynamic range necessary to observe very weak signals in the presence of strong signals. Large sample size allows for high frequency resolution. System outputs include spectral densities, amplitude probability distributions, diurnal amplitude variations, and time domain plots. Measurements were made to characterize the ELF/VLF H-field noise environment in a sampling of office buildings. These include two buildings in New York City and two Denver office buildings. Measurements were made for all hours of the day and include business day and weekend coverage. Results reveal a complicated signal environment. Associated with the power distribution frequencies were strong odd harmonics with higher harmonics evident into the kilo Hertz range; other man-made noise components were also evident. Author

N93-30746# Naval Underwater Systems Center, New London, CT.
RESULTS OF THE JOINT HIPAS/NUWC CAMPAIGNS TO INVESTIGATE ELF GENERATED BY AURORAL ELECTROJET MODULATION
PETER R. BANNISTER, RAYMOND F. INGRAM, MICHAEL J. MCCARRICK (California Univ., Los Angeles.), and ALFRED Y. WONG (California Univ., Los Angeles.) *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 12 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03
This paper reports the results of the first concerted effort (both experimentally and theoretically) to characterize the various parameters of the Extremely Low Frequency (ELF) and HIgh Power Auroral Stimulation (HIPAS) polar electrojet antenna excited by the HIPAS radiating facility. These parameters include the magnetic dipole moment, excitation height, and range and bearing dependence. The experimentally determined values of these various parameters, using a mobile ELF receiver, as well as a long distance station, are in agreement with predictions. Author (revised)

N93-30747# Communications Research Centre, Ottawa (Ontario).
VLF/LF TRANSMITTING ANTENNAS
JOHN S. BELROSE *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 22 p (SEE N93-30727 11-32) May 1993
Sponsored in part by Dept. of National Defence
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03
Very Low Frequency (VLF) transmitting antenna design is a specialized field of engineering that requires the combined skill of radio, civil, and mechanical engineers. The antenna systems used for this band (15-30 kHz) are enormous structures. Vertical radiators with very extensive top-loading (non-radiating top-hats) are necessary because the electrical height of practical towers is small. For tower heights of 300-450 meters (1000-1500 feet) the electrical heights are only fifteen to forty-five one thousandths of a wavelength. This presentation discusses the following topics: antenna design concepts, antenna fundamentals, tools for antenna modeling, a mini-study of conventional antennas, multiple tuned antenna systems, and a comparison between performance (measured and predicted) for multiple tuned antennas vs. single tuned antennas. Author (revised)

N93-30748# Defence Research Agency, London (England).
A DYNAMIC BANDWIDTH AND PHASE LINEARITY MEASUREMENT TECHNIQUE FOR 4-CHANNEL MSK VLF ANTENNA SYSTEMS
M. D. HARRINGTON *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 8 p (SEE N93-30727 11-32) May 1993
Sponsored in part by Ministry of Defence
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03
This paper presents a method for performing dynamic measurements of antenna bandwidth and phase linearity parameters for VLF transmitter systems. These measurements were undertaken in support of both National and NATO VLF MSK upgrade programs and relate to VLF transmitting antenna characteristics required in order to comply with STANAG 5030. Author (revised)

N93-30749# Defence Research Agency, London (England).
STUDY OF A VLF DISTRIBUTED ANTENNA ARRAY
G. A. ASHDOWN *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 13 p (SEE N93-30727 11-32) May 1993
Sponsored in part by Ministry of Defence
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03
This study considers the use of an array of VLF antennas distributed throughout the UK, instead of a single, high powered antenna, for submarine command broadcasts. Such an array offers survivability and environmental advantages. The coverage of the array would, however, not be omni-azimuthal, but would have nulls every few degrees as a result of the interference between the signals from the individual antennas. The study investigates the effect on the array coverage of a number of impairments (operating frequency, phase and frequency errors, and antenna loss) and discusses the advantages and disadvantages of steering the main beam to the receiving platform. Consideration is also given to how the received signal will be distorted depending on the location of the receiving platform. It was concluded that a VLF array would not be suitable for providing wide area continuous and assured communications. Author (revised)

N93-30750# Porto Univ. (Portugal). Dept. de Engenharia Electrotecnica e de Computadores.
APPLICATION OF THE FOURIER TRANSFORM TO SHORT ANTENNAS
FRANCISCO C. V. GRILO *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 7 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03
As is well known, the far field pattern of an aperture is related to a distribution of radiating sources by the Fourier Transform. In this paper, we show that it is also possible to use a Fourier Transform to perform the analysis and synthesis of short antennas. In this way, we can easily have both the analytical and graphical representation of the antenna pattern and the errors that we make with the usual approximating models. It is also possible to make use of know how from the field of signal processing to perform the analysis and synthesis of the radiation pattern. All the theory is based on the Theorem of the Small Complex Translation meaning that we can represent all the current distribution on the antenna by complex translations of an infinitesimal element of current. The correspondent pattern can be found using an adequate spatial variable representation. Author (revised)

N93-30751# IDS Ingegneria dei Sistemi S.p.A., Pisa (Italy).
ANTENNA MODELING AND ANALYSIS FOR ELF/VLF/LF APPLICATIONS
M. BANDINELLI, S. CHITI, and R. CIONI *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 9 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03
This paper presents a numerical procedure which can be effectively used for the analysis/design of a very-low frequency capacitive antenna system on complex platforms and for charge distribution computation. The 'quasi static' radiation problem was solved by means of the corresponding electrostatic solution, by using a Method Of Moments (MOM) procedure. Pulse basis functions, defined on surface patch domains, and the point-matching test procedure are used in conjunction with a powerful postprocessing numerical tool. Given the platform model, the postprocessing tool allows us to analyze all possible antenna

configurations by running the MOM computer code only once. The following parameters can be evaluated: (1) antenna radiation pattern; (2) antenna Norton equivalent circuit, from which the effective voltage at the input of the receiver can be evaluated; (3) induced charge distribution; and (4) scattered electric field distribution near the platform. The proposed solution is particularly useful for applications where the criticality of the structure requires a peculiar attention in defining structural elements that constitute the 'electrical doublet' (conformal antenna). Author (revised)

N93-30752# Naval Undersea Warfare Center, New London, CT. Submarine Electromagnetic Systems Dept.
PATTERN MEASUREMENTS OF US NAVY ELF ANTENNAS
E. A. WOLKOFF and W. A. KRAIMER *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 10 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03

The radiation pattern of an Extremely Low Frequency (ELF) transmitting antenna can be determined from field components measured at a single point. Horizontal magnetic fields from the four US Navy ELF antennas in the north central United States were measured at three receiving locations. The three resulting pattern factors for each antenna are compared and shown to be in good agreement. Author (revised)

N93-30753# SRI International Corp., Arlington, VA.
TETHERED AEROSTAT VLF/LF TRANSMITTER SYSTEM DESIGN CONSIDERATIONS
RICHARD L. CRAWFORD, THOMAS C. LAMANNA, and KENNETH L. JORDON (Science Applications International Corp., Vienna, VA.) *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 6 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A02/MF A03

A tethered aerostat VLF/LF transmitter (TAVT) system is a cost-effective, survivable alternative for reconstituting VLF/LF communications connectivity to strategic forces in a post-attack environment. This paper describes the tradeoff design considerations that led to recommending a TAVT system with a 50,000-cubic-foot aerostat and a 5,000-foot tether used as the transmitting radio antenna. The major tradeoff factors considered in choosing this design were: survivability, transportability, coverage area, operating frequency range, maximum effective radiated power, cost, and corona avoidance. Author

N93-30754# E-Systems, Inc., Greenville, TX.
VIABILITY ASSESSMENT FOR RELIABLE LONG-WAVE COMMUNICATION LINKS
T. S. CORY and T. R. HOLZHEIMER *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 17 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

This paper illustrates the viability of reliable global communications at VLF as a consequence of the insight gained by performing link analyses vs. frequency. The physical and economic reality of implementing these possibilities depends on the availability of transmit resources, possibly on a shared basis. Author (revised)

N93-30755*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
ORBITING TRANSMITTER AND ANTENNA FOR SPACEBORNE COMMUNICATIONS AT ELF/VLF TO SUBMERGED SUBMARINES
P. R. BANNISTER (Naval Undersea Warfare Center, New London, CT.), J. K. HARRISON, C. C. RUPP, R. W. P. KING (Harvard Univ., Cambridge, MA.), M. L. COSMO (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.), E. C. LORENZINI (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.), C. J. DYER (Raytheon Co., Portsmouth, RI.), and M. D. GROSSI (Raytheon Co., Portsmouth, RI.) *In* AGARD, ELF/VLF/LF Radio Propagation and Systems Aspects 14 p (SEE N93-30727 11-32) May 1993
(AGARD-CP-529) Copyright Avail: CASI HC A03/MF A03

An orbital emplacement for the transmitter and the antenna of a communications link at ELF (30 to 300 Hz) and VLF (3 kHz to 30 kHz) to submerged submarines has been considered since the very inception of the space age. However, only recently has space technology reached a sufficient level of maturity for system designers to undertake serious studies of this link configuration. The optimistic outlook stems from recent space technology developments, such as the design and construction by NASA of long orbiting tethers, and the testing, onboard Shuttle Orbiter ATLANTIS, of the first spaceborne 20 km metal wire. This is known as the Tethered Satellite System-1 (TSS-1), a space mission that might be possibly followed by other flights, with tether lengths that could reach 100 km. Once deployed at a height of, say, 300 km, from a Shuttle Orbiter, or from another suitable platform, a long, thin tether aligns itself along the local vertical by virtue of the gradient of the Earth gravity field. If made of metal, the tether can function as a VED (Vertical Electric Dipole) transmitting antenna at ELF and VLF. Author (revised)

N94-15222# Royal Ordnance PLC, Aylesbury (England).
MICROWAVE PROPERTIES AND SYSTEMS OVERVIEW
RONALD LAWRENCE *In* AGARD, Rocket Motor Plume Technology 35 p (SEE N94-15217 03-20) Jun. 1993
(AGARD-LS-188) Copyright Avail: CASI HC A03/MF A03

Of particular significance to the operational success of a missile using microwave communications is the interference introduced by the rocket exhaust plume. As a hot and turbulent gas stream the exhaust has electrical properties that can seriously degrade guidance and tracking. Also present is the potential for missile detection offered by energy scattered from microwave signals impinging upon the plume to present a radar cross section, and an exhaust signature from inherent emission sources within the plume. This paper presented in AGARD Lecture Series 188, follows from AGARD Advisory Report 287 submitted by Propulsion and Energetics Panel Working Group 21 entitled 'Terminology and Assessment Methods of Solid Propellant Rocket Exhaust Signatures.' It provides a description of microwave propagation through a rocket exhaust, the cause of signal attenuation, and the generation of phase and amplitude sideband noise. Consideration is given to the effects of missile flight velocity and altitude. Diffraction and refraction processes are discussed, particularly in relation to plumes containing high density concentrations of free electrons. Radiation sources, mainly at millimetric wavelengths, are included together with signature implications. The effects of exhaust interference with communications is examined from a system point of view and some methods of relief from the interference are considered.
Author (revised)

N94-15223# Deutsche Aerospace A.G., Munich (Germany). Dynamics Systems.
PLUME RADIATION
R. DIRSCHERL *In* AGARD, Rocket Motor Plume Technology 47 p (SEE N94-15217 03-20) Jun. 1993
(AGARD-LS-188) Copyright Avail: CASI HC A03/MF A03

The electromagnetic radiation originating from the exhaust plume of tactical missile motors is of outstanding importance for military system designers. Both missile- and countermeasure engineer rely on the knowledge of plume radiation properties, be it for guidance/interference control or for passive detection of adversary missiles. To allow access to plume radiation properties, they are characterized with respect to the radiation producing mechanisms like afterburning, its chemical constituents, and reactions as well as particle radiation. A classification of plume spectral emissivity regions is given due to the constraints imposed by available sensor technology and atmospheric propagation windows. Additionally assessment methods are presented that allow a common and general grouping of rocket motor properties into various categories. These methods describe state of the art experimental evaluation techniques as well as calculation codes that are most commonly used by developers of NATO countries. Dominant aspects influencing plume radiation are discussed and a standardized test technique is proposed for the assessment of plume radiation properties that include prediction procedures. These recommendations on terminology and assessment methods should be common to all employers of plume radiation. Special emphasis is put on the omnipresent need for self-protection by the passive detection of plume radiation in the ultraviolet (UV) and infrared (IR) spectral band. Author

N94-29566# Shape Technical Center, The Hague (Netherlands).
ACCS SURVEILLANCE EXPLORATORY PROTOTYPE (ASEP)
K. GAEBLER *In* AGARD, Machine Intelligence in Air Traffic Management 18 p (SEE N94-29558 08-04) Oct. 1993
(AGARD-CP-538) Copyright Avail: CASI HC A03/MF A04

The increasing sophistication of surveillance systems, both civilian and military, has generated a great deal of interest in techniques of multi-target tracking and sensor integration. To help SHAPE and the NATO Air Command and Control System (ACCS) Management Agency (NACMA) to specify and implement the ACCS surveillance subsystem, in particular in the areas of data fusion and identification, the SHAPE Technical Center (STC) is currently developing an ACCS Surveillance Exploratory Prototype (ASEP) as an element of its new integrated testbed. The purpose of the ASEP is to demonstrate the feasibility and operational benefits of future air picture generation systems. The significant difference between this advanced system and currently available systems is that ASEP will provide better tracking continuity, more accurate estimates of track positions, velocity, acceleration, and additional information on targets. The provision of this information on air targets is also of great importance for civil ATC systems, especially in view of growing requirements for ATC planning, conflict alert and conflict resolution. The use of multiple sensors and sources requires the fusion of different types of data, including sensor reports containing measured attributes such as the target type and other target features. Since advanced fusion algorithms are using kinematic data as well as attribute data for the identification process, the majority of all air targets can be identified automatically. This paper gives an overview of the following components that are implemented in the ACCS Surveillance Exploratory Prototype at STC: scenario generation and sensor simulation; real-time multi-sensor tracking; real-time radar data integration; external track and flight plan data integration; and air picture presentation on a Surveillance Workstation using new human-computer interface (HCI) techniques. Derived from text

N94-30495# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ATMOSPHERIC PROPAGATION EFFECTS THROUGH NATURAL AND MAN-MADE OBSCURANTS FOR VISIBLE TO MM-WAVE RADIATION [LES EFFETS DES CONDITIONS DEFAVORABLES DE PROPAGATION SUR LES SYSTEMES OPTIQUES, IR ET A ONDES MILLIMETRIQUES]
Nov. 1993 205 p In ENGLISH and FRENCH Presented at the Electromagnetic Wave Propagation Panel Symposium, Palma de Mallorca, Spain, 17-20 May 1993
(AD-A276919; AGARD-CP-542; ISBN-92-835-0727-4) Copyright Avail: CASI HC A10/MF A03

This publication reports the papers presented to a specialists' meeting held by the Electromagnetic Wave Propagation Panel at its Spring 1993 meetings. The topics covered include: the effects of natural obscurants (haze, clouds, fog, rain, snow and dust) on system performance; the effects of man-made smokes, battlefield-induced smokes and enhanced scintillation on system performance; atmospheric effects on target and background signatures, and target to background contrast; multispectral camouflage -- weather-related propagation effects on camouflage and obscurants effectiveness and contrast reduction, and theoretical and/or experimental evaluation of camouflage effectiveness; systems mitigation aspects -- methods to mitigate the above-mentioned factors, e.g., image processing, sensor fusion, tactical weather intelligence, and tactical decision aids. For individual titles, see N94-30496 through N94-30514.

N94-30496# Florence Univ. (Italy).
EVALUATION OF DUAL POLARIZATION ATTENUATION OF MILLIMETER FREQUENCIES THROUGH A METEOROLOGICAL RADAR
D. GIULI, L. BALDINI, L. FACHERIS, and P. MAZZETTI *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 9 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

The possibility of exploiting measurements obtained through a C-band dual polarization radar is examined, as an auxiliary tool for the planning of radio relays operating at millimeter frequencies. C-band weather radars, though featuring several advantages related to their cost and reduced size, provide partially attenuated rainfall measurements with respect to their S-band counterparts. However, good reliability of rainfall rates based on C-band dual polarization measurements is achieved after proper processing based on iterative procedures for propagation attenuation due to rain. A simulation program has been utilized to provide synthetic rainfall and C-band dual polarization reflectivity data related to several storms, corresponding to different meteorological conditions. Simulated data, after proper correction of radar data, have been utilized to evaluate path attenuation statistics useful to predict fading at millimeter frequencies and related outage probability. Results show that a C-band radar can be profitably exploited for the purpose, prediction being feasible under different space-time rain patterns. On the other hand, the analysis has shown that differential reflectivity is not so essential for the aforementioned purpose as absolute reflectivity, even if it could be utilized with success in real contexts for the identification of hydrometeors (hail, graupels, wet snow) other than rain, which may be responsible for more pronounced scattering and absorption phenomena. Author (revised)

N94-30497# National Telecommunications and Information Administration, Boulder, CO. Inst. for Telecommunication Sciences.
PROPAGATION MODELING OF MOIST AIR AND SUSPENDED WATER/ICE PARTICLES AT FREQUENCIES BELOW 1000 GHZ
H. J. LIEBE, G. A. HUFFORD, and M. G. COTTON *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 11 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A03/MF A03

Propagation characteristics of the atmosphere are modeled for the frequency range from 1 to 1000 GHz (1 THz) by the modular millimeter-wave propagation model MPM. Refractivity spectra of the main natural absorbers (i.e., oxygen, water-vapor, suspended droplets and ice particles) are computed from known meteorological variables. The primary contributions of dry air come from 44 O2 lines. Results from extensive 60-GHz laboratory measurements of the pressure-broadened O3 spectrum were applied to update the line data base. The water-vapor module considers 34 local H2O lines plus continuum contributions from the H2O spectrum above 1 THz, which are formulated as wing response of a pseudo-line centered at 1.8 THz Cloud/fog effects are treated with the Rayleigh approximation employing revised formulations for the permittivities of water and ice. The influence of the Earth's magnetic field on O2 absorption line becomes noticeable at altitudes between 30 and 120 km. Anisotropic medium properties result, which are computed by the Zeema propagation model ZPM. Here the elements of a complex refractivity tensor are determined in the vicinity (plus or minus 10 MHz) of O2 line centers and their effect on the propagation of plane, polarized radiowaves is evaluated. A spherically stratified (0-130 km) atmosphere provides the input for the codes MPM and ZPM in order to analyze transmission and emission properties of radio paths. Height profiles of air and water vapor densities and of the geocoded magnetic field are specified. ZPM predicts polarization- and direction-dependent propagation through the mesosphere. Emission spectra of the 9+ line (61150 plus or minus 3 MHz) for paths with tangential heights ranging from 30 to 125 km are consistent with data measured by the shuttle-based millimeter-wave limb sounder MAS. Author (revised)

N94-30498# Physics and Electronics Lab. TNO, The Hague (Netherlands).
THE INFLUENCE OF THE EVAPORATION DUCT ON THE ANGLE OF ARRIVAL AND AMPLITUDE OF THE BACKSCATTERED SIGNAL FROM TARGETS LOW ABOVE THE SEA
H. SITTROP, H. GRAVESTEIJN, and H. J. M. HEEMSKERK *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 13 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A03/MF A03

The impact of multipath and atmospheric refractions on the amplitude, the apparent Radar Cross Section, RCS(sub a), and the Angle of Arrival, AOA, of low altitude target radar backscatter at 9.4 GHz, can be described as typical for 3 ranges, and 3 duct

height intervals, i.e., respectively 6, 10, and 19 km, and 10 m, 10-18 m and 18-26 m. The targets are tri-hedrals mounted on poles injected into the sea-bed at the above mentioned ranges. Sensor height is 23 m above normal low sea-tide and the target heights vary from 4.5 m to 8 m depending on the sea-tide. Whereas the RCS(sub a) and the AOA show opposite behavior at 10 km and at 19 km, i.e. and RCS(sub a) decrease and an AOA decrease at 10 km, both for duct heights of 18-26 m, the opposite occurs for duct heights of 10-18 m. However, in this latter case no dramatic differences occur with respect to the AOA. At the 6 km range the RCS(sub a) is persistently larger (4-8 dB) than the free-space RCS(sub o), for duct heights less than 10 m, whereas the AOA is predominantly negative for all recorded duct heights (0-26 m). On the other hand the RCS(sub a) at this range reduces from circa +6 dB to -6 dB relative to RCS(sub 0) for increasing target height and duct heights of 10-26 m. This characteristics target/duct height behavior may introduce misleading information about the type of target. Particularly at long ranges (19 km) and target heights of circa 6 m, the RCS(sub a) may be -20 dB with respect to the free-space RCS(sub o), and the AOA +.6, for duct heights of 10-26 m. Detection probability reduces significantly, and if the target is detected, the height position is entirely wrong, i.e. circa +200 m, whereas the target is only 6 m above sea. At duct heights between 10-18 m the RCS(sub a), and hence the detection probability increases at 19 km. On the other hand this RCS(sub a) can be 10-20 dB lower at 10 km, particularly at target heights between 4-6 m. A lost tract at 10 km may therefore be possible, if detection was just feasible at 19 km at these duct heights. PCPEM predictions and measurements at 5.8 km show in general a fairly comparable trend for target heights between 6-7 m, however, for duct heights of 0-18 m, a too high RCS(sub a) is predicted and for the observed duct heights of 18-25 m a too low RCS(sub a). Within the region of transition from a too high to a too low prediction, comparable values are observed. For target heights between 5.5-6 m PCPEM predicts too large values for all duct heights. Author (revised)

N94-30499# Army Research Lab., White Sands Missle Range, NM. Battlefield Environment Directorate.

MULTISPECTRAL TRANSMITTANCE MEASUREMENTS THROUGH MAN-MADE WATER FOGS

YOUNG P. YEE, ROBERT A. SUTHERLAND, and JAMES L. COGAN *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 7 p (SEE N94-30495 08-32) Nov. 1993

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A fog system capable of producing water droplets with diameters between 5 and 40 micrometers was used for multispectral transmittance measurements. Measurements were conducted at an arid, desert field location on the White Sands Missile Range, New Mexico. The fog system consists of a supply of local tap water, 50 gallon holding barrels, high pressure hoses and connectors, and an array of specially designed spray nozzles. The spray nozzles have precision made .006-inch diameter orifices. Water under 1000 psi of pressure is forced through the small orifice and impacts onto a curved metal pin causing droplet formation and dispersion. Droplet size distribution of the man-made fog were measured by forward scattering particle-measuring instruments. The advantages of using the fog generation system are low energy requirements, high rates of droplet production, environmentally safe dispersion, and commercial availability. Transmittance measurements were taken by a Multi-Path Transmissometer/Radiometer (MPTR). The MPTR is capable of obtaining transmittances at .4-.7 micron, 1.0-1.1 micron, 3.5-4.8 micron, and 7.9-12.3 micron spectral bands. Results will be presented on transmittance comparisons between the different wavelength bands during varying fog density conditions. The transmittance data from the line of sight were tested for optical depth linearity in the various wavelength bands. Author

N94-30500# Army Research Lab., White Sands Missle Range, NM. Battlefield Environment Directorate.

ESTIMATION OF TRANSMITTANCE FROM SATELLITE IMAGERY

JAMES COGAN and DAVID WILLIAMS *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 10 p (SEE N94-30495 08-32) Nov. 1993

(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

Transmittance in the visible and thermal infrared may be estimated from a variety of in-situ and remote techniques using ground-based or airborne sensors. However, estimation of transmittance in the troposphere from data gathered by sensors on space platforms remains a problem, especially over land surfaces. This paper presents two preliminary methods: one to compute visibility using changes in contrast from a series of luminance images or measuring changes in the nonzero frequency amplitudes from the associated frequency domain images, and the other to calculate thermal infrared transmittance over a horizontal, vertical, or slant path that uses estimates of precipitable water from satellite data, combined with sounding data from satellite or other sources. Author

N94-30501# Arsenal du Materiel Mechanique et de l'Armement, Rocourt (Belgium).

AN EXPERIMENTAL AND COMPREHENSIVE METHOD TO MEASURE EMISSION CHARACTERISTICS [UNE METHODE EXPERIMENTALE ET GLOBALE DE MESURE DE L'EMISSIVITE]

R. MARCHAL *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 8 p (SEE N94-30495 08-32) Nov. 1993 In FRENCH

(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

The characteristics of emission may be of thermal infrared multispectral processes: either through direct measurements on the emitted flux, which are compared to a reference black body, or through measurements on reflectivity and application of the Kirchoff laws. Both approaches have advantages and drawbacks according to the type of emission characteristics that are studied. The method which is used in this study uses the first principle: it concerns itself with relatively high levels of emissions (greater than 0.5), which are directional and controlled by a given sensor. In order to maximize the precision of measurements, testing respects the following conditions: (1) lessening of residual parasite flux, through the use of low emission materials and a cooled diaphragm, thus creating a confined enclosure; (2) taking into account the residual parasite flux, through models of radiation exchange within the enclosure; (3) assessment of the homogeneity in temperature of both the sample and the reference materials; and (4) calculations on the confidence levels, in function of the variances in the beginning parameters. This use of models, added to technical advances, make it possible to build a very inexpensive test site, at least as far as specific purchases were concerned. Several comparative measurements showed that the range of measurable emissions goes from 0.5 to 1, with an absolute confidence level of 0.05 to 0.02, according to the material. The best performance was obtained when highly emissive and highly heat conductive materials were used. Transl. by FLS

N94-30503# Ministry of Defence, London (England). Chemical and Biological Defence and Pyrotechnics.

NATO SOCMET TRIALS

C. M. JENDEN *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 4 p (SEE N94-30495 08-32) Nov. 1993

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During 1993, Canada, France, Germany and the United Kingdom will be participating in the Smoke and Obscurants Countermeasures Materials Evaluation Tests (SOCMET). The tests will be carried out under the auspices of the NATO Army Armaments Group, AC/225, Panel VI, Sub-Panel 7 whose interests include multispectral smoke screening systems. The tests will comprise two sets of trials; one under cold climate conditions in Quebec, Canada, during February/March 1993 and the other in temperate conditions in Bourges, France during September 1993. This paper provides an insight into the management and aims of SOCMET. The evaluations will be seeking to identify candidate materials which create effective obscurant screens in the visible,

infrared and millimetric bands of the electromagnetic spectrum. These materials will be disseminated through a range area dispersal. A key element of the trials will be the evaluation of field test instrumentation which may eventually lead to the development of standardized evaluation techniques. Following the trials, a scientific workshop will be held to review the results. A final report will be presented to NATO which will form the basis of future collaborative developments on multispectral screening systems leading towards standard NATO documentation on smoke and obscurant systems. Author

N94-30505# Army Research Lab., Aberdeen Proving Ground, MD.
THE EFFECTS OF MAN-MADE SMOKES AND BATTLEFIELD-INDUCED SMOKES ON THE PROPAGATION OF ELECTROMAGNETIC RADIATION
ANTHONY VANDEWAL *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 6 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

This paper provides an unclassified overview of the U.S. Army program that collects and disseminates information about the effects of battlefied smokes and obscurants on weapon system performance. The primary mechanism for collecting field data is an annual exercise called SMOKE WEEK. In SMOKE WEEK testing, a complete characterization is made of the ambient test conditions, of the electromagnetic radiation propagation in clear and obscured conditions, and of the obscuring cloud that the particles that comprise the cloud. This paper describes the instrumentation and methodology employed to make these field measurements, methods of analysis, and some typical results. The effects of these realistic battlefield environments on weapons system performance are discussed generically. Author

N94-30506# Defence Research Agency, Malvern (England).
INFRARED POLARIZATION SIGNATURES
D. L. JORDAN and G. LEWIS *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 6 p (SEE N94-30495 08-32) Nov. 1993
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Target detection using passive electro-optic devices operating in the 8 to 14 micron band is often limited by background clutter. A possible method of overcoming this limitation may be to use the polarization content of the image to discriminate between man-made targets and natural background. Laboratory measurements are presented of the polarization state of 10 to 6 micron radiation reflected from, and emitted by, a range of materials. It is concluded that elliptical polarization is not of primary importance and that measurements of the degree of linear polarization appear to provide useful discrimination between man-made objects and 'natural' ones. Author (revised)

N94-30507# Centre d'Etudes et de Recherches, Toulouse (France).
MODEL FOR THE SIMULATION OF ATMOSPHERIC EFFECTS ON TARGETS TO BACKGROUND PASSIVE SIGNATURES [MODELE POUR LA SIMULATION DES EFFETS ATMOSPHERIQUES SUR LES SIGNATURES PASSIVES DE CIBLES DANS LEUR ENVIRONNEMENT]
C. WALLEZ, J. LEMORTON, P. F. COMBES, and F. CHRISTOPHE *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 12 p (SEE N94-30495 08-32) Nov. 1993 In ENGLISH and FRENCH
(AGARD-CP-542) Copyright Avail: CASI HC A03/MF A03

In order to assess very accurately the performances of millimeter wave imaging passive systems, efforts have been made towards the development of a straightforward easy to use computer code. This simulation model has been used to evaluate the influence of meteorological conditions on radiometric contrasts. The following parameters are studied: frequency, terrain emissivity, and radiometer position. A first set of simulations is done in the scatter-free atmosphere assumption. Then scattering by hydrometeors is taken into account. In each case, ground surface discrimination by their radiometric temperature is discussed. Author (revised)

N94-30508# Defence Research Agency, Malvern (England).
THE EFFECT OF ENHANCED BACKSCATTERING ON TARGET DETECTION
E. JAKEMAN, J. P. FRANK, and G. J. BALMER *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 8 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

Error probabilities are calculated for the detection of a target illuminated through a random medium in the presence of ambient noise. Comparisons are made between monostatic operation, in which double passage of the radiation leads to an enhanced amplitude and fluctuation of the received signal, and bistatic operation, where the outward and return radiation paths traverse uncorrelated regions of the intervening random medium. It is shown that although common transmit/receive optics are advantageous in the case of low signal to noise ratios, in normal regimes of operation a bistatic arrangement leads to lower total error probability, particularly when the scattering medium generates strong scintillation in the target plane. Author (revised)

N94-30509# Massachusetts Univ., Amherst, MA. Microwave Remote Sensing Lab.
POLARIMETRIC BACKSCATTER MEASUREMENTS OF NATURAL SURFACES AT MILLIMETER WAVELENGTHS
JAMES MEAD, PAUL CHANG, and ROBERT MCINTOSH *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 10 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

During the last four years, the Microwave Remote Sensing Laboratory of the University of Massachusetts has studied the polarimetric backscatter response of natural and man-made surfaces at 35, 95, and 225 GHz. These surfaces include grass, asphalt, snowcover, and trees. In addition, ground-based and airborne backscatter measurements of clouds and precipitation were made at 95 GHz. The results of these experiments are summarized by presenting histograms of normalized radar cross section for trees, snowcover, and clouds. The temporal dependence of the normalized radar cross section for snowcover is also presented for 95 and 225 GHz which shows a strong diurnal variation due to melting and refreezing. Also presented is the angular dependence of backscatter from grass and asphalt at 35, 95, and 225 GHz, as well as volume backscattering coefficients for airborne measurements of clouds and precipitation at 96 GHz. Author (revised)

N94-30510# Michigan Univ., Ann Arbor, MI. Radiation Lab.
A HYBRID ELECTROMAGNETIC-STATISTICAL APPROACH FOR CHARACTERIZING MMW SCATTERING BY TERRAIN
FAWWAZ T. ULABY, PAUL SIQUEIRA, and KAMAL SARABANDI *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 8 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

The performance of millimeter wave (MMW) radar systems in target detection, navigation, and other applications depends in part on the scattering characteristics of the terrain background. Two different approaches have been pursued in the literature for characterizing MMW scattering by terrain. The first approach relies on the development of electromagnetic scattering models that relate the backscattering coefficient sigma of a given terrain type (such as bare ground surfaces, snow cover, and vegetation) to the physical properties of the terrain target, and then verifying model predictions though experimental observations conducted under semicontrolled field conditions. The second approach is entirely empirical in nature; it relies on the acquisition of extensive radar data from which statistical distributions are generated. This paper provides an overview of how the hybrid approach can be used to simulate the statistical properties of terrain backscatter at millimeter wavelengths for several types of terrain, including bare soil surfaces, vegetation, and snow cover. The hybrid approach incorporates scintillation effects associated with coherent sensors together with information about the mix of terrain categories present in the scene. Two types of input data (or a merged set of both) can be used as input to the clutter simulation package: measured data that is available in a University of Michigan data base or data generated by electromagnetic models. The data base is

available as a handbook that contains MMW scattering observations reported in the literature for certain terrain types and conditions. Alternatively, a set of electromagnetic models can be used for calculating the backscattering coefficient sigma of the specified terrain type. These models, which are semiempirical in form, are based on highly complicated theoretical models that had been tested against experimental observations. With this approach, it is possible to generate a probability density function for the backscatter from a certain type of terrain without the need for a measured clutter data base. This is particularly attractive at millimeter wavelengths because only a limited amount of terrain clutter data is currently available. Author

N94-30511# Centre d'Etudes et de Recherches, Toulouse (France).
GRANULOMETRY IN ENVIRONMENTS WITH VERY SMALL PARTICLE CONCENTRATIONS [GRANULOMETRIE DE MILIEUX A FAIBLE CONCENTRATION DE PARTICULES]
A. DELFOUR, B. GUILLAME, and ALAIN P. JUNCHAT *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 10 p (SEE N94-30495 08-32) Nov. 1993 In FRENCH
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03
The principle of granulometry through particle light diffusion in environments with very low levels of concentration was studied. A model was built and its response, when particles were randomly distributed in the measured volume, was numerically simulated. Atmospheric, urban, rural, and seaside conditions were used in models with extended ranges of concentration. Several wavelengths of light were tested. Atmospheric aerosol granulometry is feasible if the concentration per volume is greater than or equal to 10(exp -5) ppm, and if the light wavelength is of the same order as the average size of the particles. The particles' contribution to atmospheric visibility may be measured if a preliminary calibration of the detection system is put into place. Laboratory equipment was used to validate the use of models. In order to simulate the appropriate particles' concentration, a 10 dm(exp 3) test chamber was built. Experiments, conducted with licopode powder (25 to 35 micron in diameter) in known concentration per volume, were correctly reproduced. Transl. by FLS

N94-30512# Army Research Lab., Adelphi, MD.
RADAR CROSS SECTIONS OF GROUND CLUTTER AT 95 GHZ FOR SUMMER AND FALL CONDITIONS
R. J. WELLMAN, D. R. HUTCHINS, J. L. SILVIOUS, H. DROPKIN, G. GOLDMAN, J. NEMARICH, D. A. WIKNER, and R. K. DAHLSTROM *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 12 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A03/MF A03
Radar cross section (RCS) measurements were made on an extensively instrumented ground-clutter patch over a period of one month from late summer to early fall. The instrumentation allowed collection of a full set of data on meteorological conditions, solar flux, and soil moisture content. The RCS measurements were made using a 95-GHz, polarimetric, monopulse instrumentation radar. The radar is all solid-state, coherent, frequency steppable over a 640-MHz bandwidth, and completely polarimetric for linearly or circularly polarized radiation. The clutter area measured was located in Grayling, Michigan, and consisted of a rectangular patch of ground, 50 by 100 m in area, at a range of about 100 to 250 m from the radar. The clutter patch included areas of bare sandy ground, short grass, low shrubs, evergreen trees, and deciduous trees and was similar to a NATO European environment. A wide range of atmospheric conditions were observed over the measurement period, including a few days of measurable snowfall. The paper describes analysis of the effects of different clutter types and different atmospheric conditions on the measured RCS of the clutter patch. Author (revised)

N94-30514# Bilkent Univ., Ankara (Turkey). Dept. of Electrical and Electronics Engineering.
CALCULATION OF TURBULENCE DEGRADED POINT SPREAD FUNCTION OF AN IMAGING SYSTEM
G. SAPLAKOGLU, F. ERDEN, and A. ALTINTAS *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 7 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03
The point spread function (PSF) of a turbulence degraded imaging system is statistically characterized. In particular, sufficient data and functional fits are given for the calculation of long exposure average PSF and optical transfer function (OTF). Methods are presented for the calculation of second order statistics of PSF. Author (revised)

N94-36617# McDonnell-Douglas Aerospace, Saint Louis, MO.
ICAAS PILOTED SIMULATION RESULTS
R. J. LANDY, P. J. HALSKI, and R. P. MEYER *In* AGARD, Pointing and Tracking Systems 14 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A03/MF A02
This paper reports piloted simulation results from the Integrated Control and Avionics for Air Superiority (ICAAS) piloted simulation evaluations. The program was to develop, integrate, and demonstrate critical technologies which will enable United States Air Force tactical fighter 'blue' aircraft to achieve superiority and survive when outnumbered by as much as four to one by enemy aircraft during air combat engagements. Primary emphasis was placed on beyond visual range (BVR) combat with provisions for effective transition to close-in combat. The ICAAS system was developed and tested in two stages. The first stage, called low risk ICAAS, was defined as employing aircraft and avionics technology with an initial operational date no later than 1995. The second stage, called medium risk ICAAS, was defined as employing aircraft and avionics technology with an initial operational date no later than 1998. Descriptions of the low risk and medium risk simulation configurations are given. Normalized (unclassified) results from both the low risk and medium risk ICAAS simulations are discussed. The results show the ICAAS system provided a significant improvement in air combat performance when compared to a current weapon system. Data are presented for both current generation and advanced fighter aircraft. The ICAAS technologies which are ready for flight testing in order to transition to the fighter fleet are described along with technologies needing additional development. Author (revised)

N94-36629# GEC-Marconi Avionics Ltd., Basilon, Essex (England). Navigation and Electro-Optic Systems Div.
MULTIPLE TARGET TRACK-WHILE-SCAN IN THE AIRBORNE EO ENVIRONMENT
J. MACLEAN and M. G. MCGUIGAN *In* AGARD, Pointing and Tracking Systems 12 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A03/MF A02
Since early 1991, the Electro-Optic Systems Department (EOSD) of GEC Marconi Avionics Ltd. (GMAv) has been collaborating closely with radar systems designers from GMAv's Radar System Division (RSD) to develop Multiple Target Track-While-Scan (MTTWS) algorithms for tracking applications involving the use of electro-optical sensors. This work has progressed to the stage where simulations of EO-adapted MTTWS systems are now available and are implemented in representative processing hardware. The paper gives a general 'top level' overview of the EO-adapted MTTWS design, including functional block diagrams and a description of each of its three key elements. Illustrative diagrams show the detection data path and the important decision-making processes involved in correctly identifying possible airborne targets from clutter and noise. Examples of the MTTWS simulation output are also given. This information is presented in the form of pseudo-IR imagery overlaid with the relevant track information to give an 'at-a-glance' view of system performance. A number of interesting examples effectively serve to demonstrate 'general' system performance, and superior system performance in non-standard/testing conditions. The paper hints at further extending performance in the integration of airborne radar and EO sensors, and discusses the related key issue of accurate inertial stabilization and referencing. Author

N94-36630# McMaster Univ., Hamilton (Ontario). Communications Research Lab.
MULTITARGET TRACK INITIATION USING A MODIFIED HOUGH TRANSFORM
T. LO, J. LITVA, H. LEUNG, and A. W. BRIDGEWATER *In* AGARD, Pointing and Tracking Systems 8 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02
A modified Hough transform is proposed for multitarget track initiation. The proposed technique can initiate target tracks using data from as few as three scans. Simulated data as well as real radar plot data are used to test the initiator. Results show that its performance is superior to the conventional Hough transform in terms of false track rate without degradation in the probability of track detection. Author

N94-36631# Defence Research Establishment Ottawa, Ottawa (Ontario).
RADAR TRACKING IN MULTIPATH: TECHNIQUES FOR IMPROVED PERFORMANCE
R. M. TURNER, E. RISEBOROUGH, and E. BOSSE *In* AGARD, Pointing and Tracking Systems 8 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02
The low-elevation tracking performance of naval fire-control radars may be degraded by specular multipath. Performance can be significantly improved provided the radar has sufficient frequency agility and the appropriate signal processing is used. This paper examines the performance of a number of alternative techniques: monopulse averaged over a group frequencies within the agile band, monopulse with averaging weighted according to the signal-to-noise ratio and the use of a detailed propagation model in a maximum likelihood estimation technique called the Refined Maximum Likelihood (RML) method. Simulation results are presented to show that moderate improvement can be obtained by using monopulse with frequency averaging with a better improvement given by weighted averaging, the degree of improvement increasing with agile bandwidth. Where very precise height tracking of targets in a specular multipath is required, the RML technique is best. While RML was originally developed for antenna array signal processing, it can be applied to the two sub antennas of a phase monopulse system provided a sufficient degree of frequency agility is available. In this latter application, the technique has been designated RMONO for Refined monopulse. The basis of the RML technique is presented followed by an evaluation of its performance using results obtained from two experimental trials. Author

N94-36634# Paramax Electronic, Inc., Montreal (Quebec).
CONTACT LEVEL FUSION OF RADAR AND IRST CONTACTS ON ALMOST ELECTROMAGNETICALLY SILENT PLATFORM
FRANCOIS BEGIN, MARC-ALAIN SIMARD, and PIERRE VALIN *In* AGARD, Pointing and Tracking Systems 9 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02
The fusion of data coming from dissimilar sensors (passive/active) such as the IRST and radar raises the problem of the coordinate system used in the computation of the state vector. In single sensor tracking the IRST tracks are usually computed using an angle and angle rate coordinate system. In radar tracking, the state vector and the covariance matrix are generally computed in cartesian coordinates. Recent papers have shown the advantage of the modified spherical coordinates over cartesian coordinates in tracking passively AAW targets. It is thus natural to investigate if this advantage exists for fused sensors in an almost electromagnetically silent situation. Due to the missing range of the IRST, at the contact level fusion, the cartesian form of the 'purely' linear Kalman filter cannot be used directly without making non rigorous modifications. In this case, a linearized measurement matrix (H) can be used in a modified Kalman filter. This research pursues two goals: first, it analyzes the pertinence of the spherical and modified spherical coordinate formulation of the extended Kalman filter over the cartesian coordinate formulation and second, it evaluates the extent to which the platform can stay electromagnetically silent without damaging the quality of the tracking. The analysis shows the feasibility of data fusion in all three coordinate systems. The investigations are showing equivalent or better performances for the extended Kalman filter in cartesian coordinates. Sparse radar contacts are interleaved with regular IRST contacts, the former providing occasional range measurements to be fused with the regular more accurate angular information of the IRST. Author

N95-14200# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
CHALLENGE OF FUTURE EW SYSTEM DESIGN [LES DEFIS POSES PAR LA CONCEPTION DES FUTURS SYSTEMES EW]
May 1994 147 p In English and French Symposium held in Ankara, Turkey, 18-21 Oct. 1993
(AGARD-CP-546; ISBN-92-835-0744-4) Copyright Avail: CASI HC A07/MF A02
Electronic warfare (EW) has emerged as a critical driving force in modern warfare. New generations of weapon systems directly impact EW requirements and strategies. Modern combat aircraft are faced with a drastic change of a possible threat scenario consisting of a mix of Western and Eastern weapon systems. The deployment of advanced pulse doppler radar systems in A/A and G/A application augmented by extensive electro-optic capabilities, directed energy weapons (laser or particle beam), and electromagnetic/shockwave weapons requires a detailed reassessment of NATO EW processes. The complexity and diversity of future threat scenarios necessitate changes in NATO EW system concepts, and an update of existing equipment including modifications of tactics and combinations of EW resources to improve survivability. Author (revised)

N95-14825# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Sensor and Propagation Panel.
PROPAGATION MODELLING AND DECISION AIDS FOR COMMUNICATIONS, RADAR AND NAVIGATION SYSTEMS [LA MODELISATION DE LA PROPAGATION ET AIDES A LA DECISION POUR LES SYSTEMES DE TELECOMMUNICATIONS, DE RADAR ET DE NAVIGATION]
Sep. 1994 177 p Lecture series held in Ottawa, Ontario, 4-5 Oct. 1994, in Lisbon, Portugal, 10-11 Oct. 1994, and in The Hague, Netherlands, 13-14 Oct. 1994
(AGARD-LS-196; ISBN-92-836-1004-0) Copyright Avail: CASI HC A09/MF A02
In recent years, powerful, flexible modelling tools for assessing and exploiting propagation conditions became available. Rapid advances in mini and microcomputer technology have put complex models with sophisticated user interfaces at the disposal of non-specialists. These range from system design tools to near real-time operational and tactical decision aids that include models and databases of necessary environmental parameters. Prediction tools are required for communications, radar, and navigation applications, and cover the frequency spectrum from extremely low frequency (ELF) to optical. These lectures concentrate on the prediction tools, but also cover the background required to understand the models. Topics include the ionosphere, ground wave propagation, terrain diffraction, refractive effects, hydrometers, atmopsheric gases, electro-optics, and remote sensing. For individual titles, see N95-14826 through N95-14835.

N95-14826# Defence Research Agency, Malvern (England). Radio Propagation Exploitation Group.
PROPAGATION IN THE IONOSPHERE, A
PAUL S. CANNON *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 10 p (SEE N95-14825 03-32) Sep. 1994
(AGARD-LS-196) Copyright Avail: CASI HC A02/MF A02
The use of ionospheric models and ray tracing models as components of a propagation model are discussed. These can be used as decision aids to support human interpretation of ionospheric propagation. The physical basis for ionospheric decision aids is introduced by reference to ionospheric morphology and the basic theory of ionospheric propagation, which, along with ray tracing techniques, is then reviewed. CASI

N95-14827# Defence Research Agency, Malvern (England). Radio Propagation Exploitation Group.
PROPAGATION IN THE IONOSPHERE, B
PAUL S. CANNON *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 17 p (SEE N95-14825 03-32) Sep. 1994
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02

Sophisticated computer programs or equipment, high frequency systems, satellite to ground systems and meteor burst systems are discussed with respect to ionospheric propagation models. Short term ionospheric forecasts (electron density) and geomagnetic activity level forecasts are reviewed. The goal is to design automatic decision aids which allow skilled personnel to adapt to systems operation and interpret the output from computer programs or experimental techniques. In the future, an artificial intelligence system might replace human operators in selecting and using the models and experimental techniques to best advantage. Derived from text

N95-14828# Communications Research Centre, Ottawa (Ontario).
GROUND WAVE AND DIFFRACTION, A
JIM H. WHITTEKER *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 13 p (SEE N95-14825 03-32) Sep. 1994
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02

This lecture on ground wave and diffraction deals with the attenuation of a radio signal resulting from its interaction with the ground, and in some cases, with its interaction with objects on the ground. At lower frequencies, the electrical characteristics of the ground are very important, and the height variations less so, while at higher frequencies, the opposite is true. At lower frequencies the wave is usually vertically polarized, since antennas are close to the ground in terms of wavelength and a horizontally polarized wave tends to be shorted out by the conductivity of the earth. At the higher frequencies, both polarizations are used, and at the highest frequencies, it makes little difference which is used. Derived from text

N95-14829# Communications Research Centre, Ottawa (Ontario).
GROUND WAVE AND DIFFRACTION, B
JIM H. WHITTEKER *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 14 p (SEE N95-14825 03-32) Sep. 1994
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02

This lecture describes a range of tools, most but not all of them computer-based. These planning tools range from simple equations and graphs to computer programs that do intensive calculations based on detailed terrain data for examining ground wave and diffraction phenomena. Derived from text

N95-14830# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
SENSING OF RADIO REFRACTIVITY AND AEROSOL EXTINCTION
JUERGEN H. RICHTER *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 17 p (SEE N95-14825 03-32) Sep. 1994 Sponsored by ONR
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02

Sensing of radio refractivity has historically been accomplished with direct sensing techniques such as radiosondes. While direct sensing techniques provide good data for propagation assessment purposes, remotely sensed data would be more desirable. Various direct and remote sensing techniques and an assessment of their potential operational usefulness are reviewed. Included are radiosondes, refractometers, radar sounders, lidars, satellite-based sensors, radiometric and radio propagation techniques. The need for and feasibility of providing three-dimensional, time-varying refractivity fields for propagation assessment are addressed. Aerosol extinction is often the atmospheric parameter limiting electrooptical systems performance. For proper performance assessment, slant path extinction must be known. For several decades, attempts have been made to infer aerosol extinction from lidar backscatter measurements. A discussion of selected lidar techniques and their limitations is presented. Author

N95-14831# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
REFRACTIVE EFFECTS FROM VHF TO EHF. PART A: PROPAGATION MECHANISMS
HERBERT V. HITNEY *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 13 p (SEE N95-14825 03-32) Sep. 1994 Sponsored by ONR
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02

Radio wave propagation in the very high frequency (VHF) to extremely high frequency (EHF) bands at low elevation angles and near the earth's surface is almost always affected by refraction. This lecture details these effects and the various methods used to model them, from simple effective-earth-radius factors for standard refraction to parabolic-equation methods for range-dependent ducting environments. Refraction and Snell's law are discussed and standard and nonstandard propagation mechanisms are defined. To establish the significance of nonstandard propagation effects, some statistics on the occurrence of ducting around the world are presented. Author (revised)

N95-14832# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
REFRACTIVE EFFECTS FROM VHF TO EHF. PART B: PROPAGATION MODELS
HERBERT V. HITNEY *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 18 p (SEE N95-14825 03-32) Sep. 1994 Sponsored by ONR
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02

This lecture describes and discusses propagation models used to assess radio propagation effects, and uses examples from propagation assessment systems and other propagation software to illustrate many of the effects. Frequencies from about 30 MHz to 100 GHz are considered. Both standard and nonstandard propagation models are described. A brief description of three propagation assessment systems that include the various models is given, and several application examples are presented to illustrate both the propagation effects and the applicability of the models. Author (revised)

N95-14833# Forschungsinstitut fuer Optik, Tuebingen (Germany).
ELECTRO-OPTICS: PROPAGATION FROM IR TO UV AND SENSOR CONSIDERATIONS. PART A: PROPAGATION THEORY
ANTON KOHNLE *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 19 p (SEE N95-14825 03-32) Sep. 1994
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02

The basic propagation theory is presented in a form usable for electro-optical systems engineers. Starting with the different contributions which affect an electro-optical system under environmental conditions (background, target-signature, atmospheric propagation, sensor specifications, signal-processing) the atmospheric transmittance separated into molecular and particle contributions is discussed. Both absorption and scattering terms as well as scattering functions are given with respect to their wavelength dependence. For statistical system performance analysis extinction coefficients for Nd:YAG and CO2 laser radiation derived from measured OPAQUE data of Southern Germany are discussed. They are given as a function of the month of the year for specific cumulative probabilities. Optical turbulence which is affecting laser systems more than broad band systems is discussed with emphasis on intensity and phase fluctuation in the atmospheric boundary layer. Nonlinear effects encountered in high-energy laser beam propagation through the atmosphere are illustrated. Author

N95-14834# Forschungsinstitut fuer Optik, Tuebingen (Germany).
ELECTRO-OPTICS: PROPAGATION FROM IR TO UV AND SENSOR CONSIDERATIONS. PART B: TOOLS FOR EXPLOITATION OF PROPAGATION CONDITIONS AND SYSTEM RANGE PERFORMANCE
ANTON KOHNLE *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 20 p (SEE N95-14825 03-32) Sep. 1994
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02
During the last decade powerful modelling tools for the assessment and exploitation of propagation conditions together with range performance models for military systems have become available. After a theoretical description of the propagation environment together with relevant effects on system performance some of the most commonly used models are described.
Author (revised)

N95-14835# Rutherford Appleton Lab., Chilton (England). Radio Communications Research Unit.
EFFECTS OF HYDROMETEORS AND ATMOSPHERIC GASES AT SHF/EHF
KEN H. CRAIG *In* AGARD, Propagation Modelling and Decision Aids for Communications, Radar and Navigation Systems 16 p (SEE N95-14825 03-32) Sep. 1994
(AGARD-LS-196) Copyright Avail: CASI HC A03/MF A02
The presence of rain on a propagation path can cause severe attenuation in the super high frequency (SHF) and extremely high frequency (EHF) frequency bands, reducing the performance of communications and radar systems. Rain, snow and ice can also give rise to scatter, causing radar clutter and the potential for interference to, and an increased probability of intercept of communications links. The structure of precipitation and cloud is discussed, and an overview of the physics of scatter of electromagnetic waves by rain is given. This is followed by a description of practical, statistical methods for the prediction of rain attenuation on terrestrial, radar and satcom systems, and simple cross section models for radar clutter and bistatic scatter. Atmospheric gases absorb energy from electromagnetic waves because of molecular resonances at particular frequencies in the SHF and EHF bands. The mechanisms are discussed and practical prediction procedures for the calculation of gaseous attenuation given.
Author

N95-20658# Alenia, Turin (Italy). Div. Avionica Apparati Speciali.
ELECTROMAGNETIC COMPATIBILITY EFFECTS OF ADVANCED PACKAGING CONFIGURATIONS
B. AUDONE, L. BOLLA, and D. TARDUCCI *In* AGARD, Advanced Packaging Concepts for Digital Avionics 5 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A01/MF A03
The Electromagnetic Compatibility (EMC) of digital avionic equipments assumes ever larger dimensions especially in the light of the tendency of modern technology aimed at higher data transmission rates and therefore higher clock frequencies and, at the same time, higher component density with reduced consumption. The emission and susceptibility problems commonly encountered in digital circuits are examined indicating critical areas and practicable suggestions to improve design techniques.
Author

N95-20921# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
MULTIPLE MECHANISM PROPAGATION PATHS (MMPPS): THEIR CHARACTERISATION AND INFLUENCE ON SYSTEM DESIGN [LES TRAJETS DE PROPAGATION DES ONDES A MECANISMES MULTIPLES (MMPP): CARACTERES ET INCIDENCES SUR LA CONCEPTION DES SYSTEMES]
Jul. 1994 415 p In ENGLISH and FRENCH Symposium held in Rotterdam, Netherlands, 4-7 Oct. 1993 Original contains color illustrations
(AGARD-CP-543; ISBN-92-835-0750-9) Copyright Avail: CASI HC A18/MF A04
This publication reports the papers presented to a specialists' meeting held by the Electromagnetic Wave propagation Panel at its Fall 1993 meeting. The topics covered on the occasion of that symposium on the subject of 'Multiple Mechanism Propagation Paths (MMPP's): Their Characterization and Influence on System Design' included: (1) propagation and noise aspects; (2) examples of MMPP systems; (3) system design to exploit or reduce the effects of MMPP's; and (4) future work. For individual titles, see N95-20922 through N95-20961.

N95-20922# Shape Technical Center, The Hague (Netherlands). Communications Div.
HIGHLY SURVIVABLE COMMUNICATIONS: COMPLEMENTARY MEDIA PACKET SWITCHED NETWORKS
D. YAVUZ, F. EKEN, and N. KARAVASSILIS *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 14 p (SEE N95-20921 06-32) Jul. 1994
(AGARD-CP-543) Copyright Avail: CASI HC A03/MF A04
The requirement for highly survivable communications (HSC) for essential command functions in military operations does not need any justification. The ability to communicate under extreme jamming levels and adverse propagation conditions, including high altitude nuclear events, is a very important requirement. There are also many natural disaster related requirements that also need such highly survivable communications. The prevalent and in a sense classical, approach to provide highly assured connectivity can be summarized as follows: Take a particular propagation medium and try to obtain the ultimate performance from it. There are many examples of this philosophy some successful, most not. Our approach, on the other hand, is to use complementary multi-media or mixed-media where communication links utilizing essentially commercial-off-the-shelf (COTS) equipment are integrated using packet radio (PR) techniques. There is also, in our view, an even more fundamental, recently discovered consideration why the expectation of continuous incremental refinement of a system using a given single media may be be achievable. This is derived from the theory of 'deterministic uncertainty' or more popularly known as 'theory of CHAOS', systems whose state space behavior has fractal characteristics. We will elaborate on this novel argument. Complementary multi-media approach has been the focus for all HSC communications activities at STC since 1982. The original STC studies and prototypes were in response to requirements of broadcasting (i.e., one-way transmission) information. A high frequency (HF)/meteorburst (MB) system was developed/prototyped/tested demonstrating the cost effectiveness of the approach. These results are reviewed. More recently, in 1992 STC has completed the development/test of an Open Systems Interconnection (OSI) HF packet radio protocol as no such open or non-proprietary protocol exists. This protocol has been fully tested, documented and made available to all NATO nations/industries. These extensive results show that significant improvements in throughput of up to many times are obtained. A similar development for an OSI MB protocol has also been completed and combined with the HF protocol to obtain an OSI HF/MB link layer protocol with unique properties for HSC networks. Description of these protocols and the relevant results are presented. The conclusion is that, HSC networks using standard COTS transceivers/modems with OSI PRO protocols can provide highly survivable connectivity, by providing the most important ingredient of survivability, media diversity.
Author

N95-20923# Shape Technical Center, The Hague (Netherlands).
QOS DRIVEN ROUTING IN PACKET SWITCHED NETWORKS OF MULTIPLE TRANSMISSION MEDIA
C. TAMVACLIS *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 9 p (SEE N95-20921 06-32) Jul. 1994
(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04
This paper discusses the application of Quality of Service (QoS) driven routing on packet-swtiched, heterogeneous networks. It is assumed that the network makes use of multiple transmission media of different types including narrowband radio based media such as those used in military tactical and emergency networks, e.g. ECCM SATCOM, HF radio, etc. A critical problem in the operation of such networks is the volatile performance of the transmission media, compounded by the fact that each transmission medium may respond differently to stress conditions. QoS driven routing provides an effective way to handle transmission media

performance fluctuations and optimizing the use of all the available communication resources. QoS driven routing means that packet routes are selected according to a global optimization criterion that takes into account not only network connectivity, but also the application QoS requirements, and the currently available QoS from the network links. A routing architecture is described for implementing QoS driven routing on a connectionless internetwork of multiple transmission media. This architecture is based on the use of civilian networking standards and it is implementable using commercial off-the-shelf equipment. Author

N95-20924# Hull Univ. (England). Dept. of Electronic Engineering.

A MMPP COMMUNICATIONS SYSTEM FOR THE FREQUENCY RANGE 2-200MHZ

M. DARNELL, P. WALKER, N. RILEY, and G. VONGAS (Defence Research Agency, Cosham, England.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterixation and Influence on System Design 11 p (SEE N95-20921 06-32) Jul. 1994

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This paper describes the work being carried out to realize a robust digital radio communications system, operational over the frequency range 2-200MHz, which will utilize the existence of multiple mechanism propagation paths (MMPP'S) in order to maximize link-availability. The system incorporates a substantial element of PC-based Digital Signal Processing (DSP). This work is essentially a unification of several areas of ongoing research within the Hull-Lancaster Communications Research Group (HLCRG) on the application of PC and DSP technology in radio system design. Author

N95-20925# Hull Univ. (England). Hull-Lancaster Communications Research Group.

MODELLING AND SIMULATION OF HF/VHF MMPPS

N. G. RILEY, M. DARNELL, and G. VONGAS (Defence Research Agency, Cosham, England.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 10 p (SEE N95-20921 06-32) Jul. 1994

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Modelling codes exist for many of the propagation mechanisms which may prevail in the frequency range of approximately 2 to 200MHz and many of the models are embodied in CCIR recommendations. Within the past few years, a number of simulation codes have been developed for use within various projects carried out by the Hull-Lancaster Communications Research Group (HLCRG). The proposed paper will describe current work aimed at bringing together the various models and simulation codes in order to produce a realistic simulation of the multiple mechanism propagation path. The multiple mechanisms under consideration conventionally include groundware, ionospheric skywave, sporadic E, ducting and the various scatter modes. In addition, recent work carried out by the HLCRG has revealed that tropospheric reflection may be responsible for stable propagation which is usable in the frequency range 30 to 70MHz for short (up to 400km) over the horizon paths. The development of a propagation model for this mechanism will be included in the presentation. Author

N95-20926# Lancaster Univ. (England). Dept. of Engineering.

ADAPTIVE ERROR-CONTROL SCHEME FOR 2-200 MHZ MULTIPLE-MECHANISM PROPAGATION PATHS

B. HONARY, M. DARNELL (Hull Univ., England.), and G. VONGAS (Defence Research Agency, Cosham, England.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 6 p (SEE N95-20921 06-32) Jul. 1994

(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

In automatic repeat request (ARQ) systems, i.e. those that depend on feedback from the receiver as to the state of the received message, relatively low 'overhead' check digits are required for reliable error detection. A properly designed system of this type can be very reliable, but under poor channel conditions the number of repetitions become excessive. Forward error correction techniques that can correct a mixture of burst and random errors are most suitable for predictable real channels. Recently, an adaptive coding technique has been introduced. The main purpose of an adaptive coding scheme is to permit only the necessary degree of error correction to be applied to the transmitted information according to the channel conditions. The concatenated codes, first introduced by Forney, are formed by cascading two encoders, an inner and outer, where the first is usually a linear binary code, or a combination of two linear binary codes, and the outer is usually a multi-level Reed-Solomon (RS) code over GF(2 exp m). It is known, that with choice of inner and outer codes, concatenated codes become very powerful codes for random and burst error correction. The objective of the proposed paper is to investigate adaptive concatenated codes, which can provide a more efficient error protection in channels with different types of errors. Derived from text

N95-20927# Hull Univ. (England). Dept. of Electronic Engineering.

PASSIVE MONITORING FOR AUTOMATED MMPP COMMUNICATION SYSTEMS

N. G. RILEY *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on Systems and Defence Research Agency 12 p (SEE N95-20921 06-32) Jul. 1994 Sponsored by GEC-Marconi Communication Systems and Defence Research Agency

(AGARD-CP-543) Copyright Avail: CASI HC A03/MF A04

A recently completed study of passive sensing techniques for hf communication systems has shown that these sensing techniques can yield data which may be of use in the control of adaptive hf communication systems. The aim of this paper is to review work carried out to date on these techniques and to examine the feasibility of applying similar techniques to radio systems utilizing higher carrier frequencies, up to around 200MHz, where many propagation modes other than ionospheric skywave may exist. Whilst inputs for the control of adaptive radio systems may be derived from a number of sources, many techniques, such as pilot-tone soundings and the transmission of training sequences, involve radiation of signals which may be undesirable in a tactical situation. System control information may also be derived by monitoring other signals which are already present in related parts of the radio spectrum, allowing more covert operation and avoiding unnecessary pollution of the radio spectrum. Derivation of such control information for use in hf systems has been studied in some detail, utilizing the following types of radio signals existing in the hf band: swept frequency sounder signals radiated by other uses of the hf spectrum, broadcast signals, standard time signals, meteorological data signals (RTTY), and overall statistical occupancy measurements of the spectrum. Some of these techniques would also be applicable to the multimechanism case, provided that the more complex propagation inversion, which is due to the greater range of propagation mechanisms available, can be taken into account. Additional, higher frequency, sources of RF energy which may provide data through passive monitoring, include aeronautical navigation beacons, amateur beacons and various types of radar signals. Use may also be made of low-orbiting satellite signals, although these present tracking problems in terms of doppler shift and give data mainly related to ionospheric scintillation and hence magnetic storm effects. Author

N95-20928# Defence Research Agency, Malvern (England). Radio Propagation Group.

THE RELATIVE IMPORTANCE OF METEOR BURST AND OTHER DISTANCE POLAR CAP PROPAGATION MODES IN THE LOW VHF BAND

PAUL S. CANNON, JAY A. WEITZEN (Massachusetts Univ., Lowell, MA.), JENS OSTERGAARD (Phillips Lab., Hanscom AFB, MA.), and JOHN E. RASMUSSEN (Phillips Lab., Hanscom AFB, MA.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 8 p (SEE N95-20921 06-32) Jul. 1994

(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

We have analyzed the duty cycle from a very high frequency polar cap path in Greenland. We find that at 35 MHz and 45 MHz the path is often sustained by sporadic E layers rather than by meteor scatter. At the higher frequencies of 65 MHz and 85 MHz we find that the path is generally dominated by meteor scatter modes. The diurnal, seasonal and geomagnetic variations of sporadic E are examined and off line decision aid models are provided to evaluate the magnitude of multiple mechanism propagation on the path. Author

N95-20929# Rennes Univ. (France). Lab. de Radiocommunications.

STUDY OF THE FAST AND SLOW VARIATIONS OF THE POWER RECEIVED AT VHF LINKS BY TROPOSPHERIC DIFFUSION [ETUDE DE VARIATIONS RAPIDS ET LENTES DE LA PUISSANCE RECUE LORS DE LIASONS VHF PAR DIFFUSION TROPOSPHERIQUE]

O. RAVARD, F. CHEVRIER, L. BERTEL, and J. C. LEJANNIC (Centre d'Electronique de l'Armement, Rennes Armees, France.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 12 p (SEE N95-20921 06-32) Jul. 1994 In FRENCH
(AGARD-CP-543) Copyright Avail: CASI HC A03/MF A04

This paper deals with some experimental results. These correspond to radio links operating in the low VHF band (30 - 80 MHz) and in the range 300 - 500 km. For those distances and frequencies, the received signal is affected by fast and slow variations. On the one hand, time-frequency analysis (wavelength transform) shows that the mainly dominant propagation mode is due to partial reflection on random surfaces (sheets). At a given time, only three or four reflections are significant and contribute to the received power. On the other hand, statistics of slow variations are examined and a log-normal distribution is observed. These slow variations are correlated with meteorological data (radiosonde). Best correlations are obtained with atmospheric pressure, refractive index and height of the tropopause. Author

N95-20930# Paris-Sud Univ., Orsay (France). Lab. d'Electronique et de Technologie de l'Informatique.

PROBLEMS OF CODING IN MULTIPATH CHANNELS [LES PROBLEMES DE CODAGE DANS LES CANAUX A TRAJETS MULTIPLES]

C. GOUTELARD *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 9 p (SEE N95-20921 06-32) Jul. 1994 In FRENCH
(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

Transmission channels are essentially multipaths. Multipaths are introduced by birefringences of the medium as in the ionosphere, by inhomogeneity as in the ionosphere and troposphere, or by reflections on obstacles as in urban or tropospheric links. The multipaths create phenomena of interference which introduce modifications of amplitude and phase of the transfer function of the channel. The stationarity of the channels complicates their use, in particular in numerical telecommunications or in teledetection. Countermeasures for fading problems call upon particular techniques of modulation or coding devices. The choice, a priori, of a modulation to carry out a system of telecommunication often involves a complexity of coding necessary to correct the errors introduced by the channel. A general method for the analysis of the channels and choice of the modulation and coding is proposed in this presentation. It is shown that the optimum choice cannot be done without an analysis of the distribution of the errors which depends on the transfer function of the channel, but also on the noise and the interferences. From the knowledge of the transfer function, interferences and noise, it is shown that a general method can be created resulting in a model of error distribution that can support code selection. The codes to be used are often very complex. The technique of interlacing can be used to avoid packages of errors, however quasi interval fadings which appear in the channels with multipaths often make regular interlacing ineffective and it then becomes necessary to consider random or pseudo-random interlacing. Transl. by CASI

N95-20931# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Research, Development, Test and Evaluation Div.

TERRAIN AND REFRACTIVITY EFFECTS ON NON-OPTICAL PATHS

AMALIA E. BARRIOS *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 9 p (SEE N95-20921 06-32) Jul. 1994
(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

The split-step parabolic equation (SSPE) has been used extensively to model tropospheric propagation over the sea, but recent efforts have extended this method to propagation over arbitrary terrain. At the Naval Command, Control and Ocean Surveillance Center (NCCOSC), Research, Development, Test and Evaluation Division, a split-step Terrain Parabolic Equation Model (TPEM) has been developed that takes into account variable terrain and range-dependent refractivity profiles. While TPEM has been previously shown to compare favorably with measured data and other existing terrain models, two alternative methods to model radiowave propagation over terrain, implemented within TPEM, will be presented that give a two to ten-fold decrease in execution time. These two methods are also shown to agree well with measured data. Author

N95-20932# Thomson-CSF, Velizy (France). Centre d'Applications Radars.

METHODS FOR EVALUATING THE EFFECTS OF CONDUITS AT THE SURFACE OF THE SEA [METHODES D'EVALUATION DE L'EFFET DES CONDUITS A LA SURFACE DE LA MER]

MICHEL FOURNIER *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 14 p (SEE N95-20921 06-32) Jul. 1994 In FRENCH Sponsored by Direction des Recherches, Etudes et Techniques
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The propagation of radio waves in the atmosphere is determined by the index of refraction which is sensitive to the pressure, temperature and moisture of the air. In the vicinity of the surface of the sea, there is a strong gradient of moisture related to the evaporation of water; it gives rise to a fast decrease of the index of the air creating a conduit of propagation in vicinity of surface. A source located in the interior of the conduit (i.e., at an altitude ranging between that of the minimum of the modified index and sea surface) sees most of its energy remaining captive inside this conduit. This has as an operational consequence - a considerable increase in the range of the radio hardware working in the vicinity of the surface of the sea. In addition, the propagation inside the conduit is characterized by the presence of multipaths related to the successive reflection of the .electromagnetic wave on the surface of the sea and the boundary of the conduit. What results is a series of reinforcements and attenuations of the field being propagated in the conduit. Taking into account the practical importance of these effects it is advisable to have suitable methods of evaluation. In this talk three methods are examined: (1) parabolic equation method, (2) method of modes, and (3) method of geometrical optics. The parabolic equation method consists of making an approximation of the wave equation by supposing that the field is propagated around a primary direction. Under these conditions one reduces the equation of propagation to a partial derivative equation of parabolic type which leads to an easy algorithm to work with. The method of modes makes it possible to carry out calculations in an entirely analytical way by supposing that the profile of the index follows a simple law. This method constitutes an analytical reference with respect to the two other methods which are numerical. The method of geometric optics is an asymptotic method. It consists of considering the trajectory of the rays resulting from the source by solving the eikonal equation. The intensity of the electromagnetic field can be given in conjunction with the equation of the trajectories; the calculation of the divergence of the wave vector tangent to the ray passing by the point where the field is evaluated. One thus obtains a system of ordinary differential equations which can be solved numerically by the method of Runge-Kutta. Each one of these methods is analyzed and a comparison between them is carried out on a number of concrete examples. In each case the theoretical limits, the advantages, and the limits of use of the three methods are highlighted. Transl. by CASI

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PROPAGATION OF HIGH FREQUENCY WAVES IN URBAN AND ROAD TUNNEL ENVIRONMENTS [PROPAGATION DES ONDES HAUTE FREQUENCE EN MILIEU URBAIN ET EN TUNNEL ROUTIER]

M. LIENARD, PH. MARIAGE, S. BARANOWSKI, and P. DEGAUQUE *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 12 p (SEE N95-20921 06-32) Jul. 1994 In FRENCH Sponsored by INRETS/CRESTA, SIRTI, ISSEP, ALCATEL Cables, and AEG Kabel
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Telecommunication between a fixed basic station and a vehicle moving on the surface of the ground are subjected to multiple

reflections. When the frequency of the carrier is of the order or higher than 1 GHz, the majority of the obstacles located between the emitter and the receiver has dimensions much larger than the wavelength and a predictive model of the conditions of propagation can be based on the theory of rays and in particular on the uniform theory of diffraction (UTD). The first part of this article presents a brief review of the mathematical formalism and the way of introducing the complex permittivity of the ground into the ideal models. In the case of propagation in an urban environment, a comparison between the results obtained using the UTD and those based on approximate models which account for multiple diffractions is carried out. An important geometrical configuration for which the multiple reflections play a very important part relates to the propagations in tunnels. The analysis is undertaken by successively considering the intrinsic propagation in the tunnel, i.e. by supposing that the tunnel is infinitely long, then the free-tunnel transition space. The study is carried out in the frequency domain then temporal domain closely connected to highlight the fluctuations of amplitude of the signal and the delays to the multipaths. The theoretical predictions are then compared with the experimental results. Transl. by CASI

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A WIDEBAND PROPAGATION SIMULATOR FOR HIGH SPEED MOBILE RADIO COMMUNICATIONS

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Multipath, jamming, listening and detection are the main limitations for mobile radio communications. Spread spectrum techniques, especially frequency hopping, can be used to avoid these problems. Therefore, a wideband simulation for multipath mobile channels appeared the most appropriate evaluation technique. It also gives useful indications for system characteristic improvements. This paper presents the design and realization of a new UHF-VHF propagation simulator, which can be considered as an extended version of Bussgang's one. This frequency hopping simulator (up to 100,000 hops per second) is wideband thus capable to deal with spread spectrum signals. As it generates up to 16 paths, it can be used in almost all mobile radio propagation situations. Moreover, it is also able to simulate high mobile relative speeds up to 2000km/h such as air-air communication systems. This simulator can reproduce, in laboratory, 16 rays Rician or Rayleigh fading channels with a maximum time delay of about 15 ms. At the highest frequency of 1200 MHz, Doppler rates up to 2 kHz can be generated corresponding to vehicle speeds up to 2000 km/h. Let note that the Bussgang simulator was defined for narrowband and fixed radio communications. In both equipments, in-phase and quadrature signals are obtained using two numerical transversal filters. Simulation results were derived in various situations especially in terrestrial urban and suburban environments, where they could be compared with measurements. The main advantage of the simulator lies in its capacity to simulate the high speed and wideband mobile radio communication channels. Author

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COMBINED EFFECTS OF ATMOSPHERE AND TERRAIN ON UHF/MICROWAVE PATHS

M. F. LEVY *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 8 p (SEE N95-20921 06-32) Jul. 1994 Sponsored by DTI

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Radiowave propagation on mixed land/sea paths is affected by both atmospheric refraction and terrain effects. The parabolic equation method provides a numerical solution for calculation of field-strength in these circumstances. We give a few applications of the finite-difference PE method, which is particularly well-adapted to problems where ground effects are important. A case in point is that of detection of low targets above a rough sea surface. For air-defense applications, PE computing requirements are prohibitive. We describe a novel method, the horizontal PE method, which allows fast computation of signal strength in large domains, and apply it to calculations of radar coverage. Author

N95-20936# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Research, Development, Test and Evaluation Div.

MODELING TROPOSPHERIC DUCTING EFFECTS ON SATELLITE-TO-GROUND PATHS

HERBERT V. HITNEY *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 5 p (SEE N95-20921 06-32) Jul. 1994

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Satellite-to-ground propagation paths are frequently affected by tropospheric refraction and ducting at very low elevation angles. Common effects are substantial enhancements of signals at ranges that would normally be beyond the horizon, and severe distortions of the patterns created by the coherent interferences of multiple propagation paths, in particular the direct and sea-reflected signals. Traditional methods to model tropospheric ducting effects, such as waveguide or parabolic equation methods, are difficult to apply to typical satellite heights. This paper will describe a parabolic-equation and ray-optics hybrid method to model these sometimes important effects, and compare modelled and measured results using a 1000-km high satellite transmitting at 1239 and 2891 MHz. Author

N95-20937# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Research, Development, Test and Evaluation Div.

THE LORENTZ RECIPROCITY THEOREM AS A CONSISTENCY TEST FOR PROPAGATION MODELS

RICHARD A. PAULUS *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 8 p (SEE N95-20921 06-32) Jul. 1994

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Modeling of electromagnetic propagation in the troposphere has been advanced in the last decade to the point where both the vertical and horizontal variation of refractivity can be accommodated readily. In particular, parabolic equation models inherently allow for lateral and vertical inhomogeneities. A hybrid ray-optics/parabolic equation model is utilized to predict propagation loss for a range-varying refractive structure to demonstrate the model obeys the Sommerfeld-Pfrang statement of the Lorentz Reciprocity Theorem. Author

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MODELLING OF MICROWAVE PROPAGATION AND CLUTTER IN A MARITIME ENVIRONMENT

M. H. VOGEL *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs:) Their Characterisation and Influence on System Design 6 p (SEE N95-20921 06-32) Jul. 1994

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For a radar system in a maritime environment, the probability of detection of a target at a low altitude is strongly dependent on the conditions of the atmosphere and the sea surface. In order to determine the detection probability of a target at low altitude, these conditions should be taken into account. This paper presents numerical methods to calculate electromagnetic propagation in an evaporation duct and to calculate sea clutter returns. Author

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SIMULATION OF THE IMPACT OF ATMOSPHERIC TURBULENCES ON MILLIMETER-WAVE COMMUNICATIONS SYSTEMS

H. VASSEUR and D. VANHOENACKER *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 13 p (SEE N95-20921 06-32) Jul. 1994 Sponsored by ESA

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By inducing scintillation of the transmitted signals, atmospheric turbulence affect both satellite and line-of-sight communication systems in the millimeter-waves range. After a characterization of the scintillation effect from theory and experiments, this paper presents two deterministic models developed at the Microwaves Laboratory U.C.L. for the simulation of scintillation. The first model accounts for the physical process of cloud induced turbulence

that yields scintillation on satellite links and the second one deals with the turbulence in the lower atmospheric layer that affects terrestrial paths. These models allow to retrieve the turbulent configuration that produce scintillation, to simulate the scintillation effects on various links and finally to predict the impact of scintillation on the performances of communication systems. Author

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PROPAGATION MEASUREMENTS ON A TROPOSCATTER LINK IN THE CANADIAN HIGH ARCTIC

C. BILODEAU and K. S. MCCORMICK *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 7 p (SEE N95-20921 06-32) Jul. 1994 Sponsored by Dept. of National Defence
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Experimental results of radio propagation measurements at 853 MHz are given for a 500 km troposcatter link in the Canadian High Arctic. The experimental data were acquired using a narrow band measurement system that was developed to permit a transmitting power of only 100 Watts while using a 4.5 meter dish at each end of the link. The system includes a digital signal processor (DSP) receiver for signal strength computation and a high stability noise source reference for amplitude calibration. The main characteristics of this system are described in this paper. Detailed fading distributions are presented for examples of slow and fast fading periods and compared with Rayleigh distributions. An estimate of the long term median path loss is made and compared with values predicted using accepted techniques. The results are believed to be the first ever presented for a microwave troposcatter link above the 80th parallel. Author

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LARGE BISTATIC ANGLE CLUTTER DEPOLARIZATION STUDY

D. J. MCLAUGHLIN, E. BOLTNIEW, J. BARCLAY, R. S. RAGHAVAN, and M. J. SOWA (Rome Lab., Hanscom AFB, MA.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 10 p (SEE N95-20921 06-32) Jul. 1994
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A bistatic radar test bed has recently been developed to measure the depolarization behavior of clutter at large bistatic angles in Eastern Massachusetts. Results presented in this paper describe the co- and cross-polarized S-Band NRCS for low resolution (300m by 300m) forested clutter cells viewed at low grazing angles. We also describe the variation in mean scattered power versus linear receiver antenna orientation angle for both vertical and horizontal transmitted polarizations. Measurements of a 20 km by 20 km region of rolling hills show that vertical copolarized NRCS exceeds horizontal copolarized NRCS by an average of 8 dB over a range of bistatic angles from 100 degrees to 160 degrees. The average polarization ratio is minus 12 dB for vertical transmitter polarization and minus 5 dB for horizontal transmitter polarization. For both transmitter polarizations and variable linear receiver antenna polarization, maximum scatter power was observed when transmitter and receiver antennas were copolarized while minimum received power was observed when the antennas were crosspolarized. Power fluctuation statistical distributions are approximately exponential for all linear receiver antenna polarization angles. Author

N95-20942# Centre de Recherches en Physique de l'Environnement, Velizy (France).

TIME BEHAVIOR AND FREQUENCY RESPONSE OF THE MICROWAVE PROPAGATION CHANNEL DURING MULTIPATH PROPAGATION

D. RANA, M. SYLVAIN, and A. R. WEBSTER (University of Western Ontario, London, Ontario.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 12 p (SEE N95-20921 06-32) Jul. 1994 Sponsored in part by the Communications Research Centre and the Natural Sciences and Engineering Research Council of Canada
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In this paper, ray-tracing simulation is used to model the dynamic behavior of the propagation channel in presence of a single super-refractive layer. Three typical mechanisms of layer formation and evolution are simulated according to experimental observations. (1) A ground-based layer formed by nocturnal cooling of the Earth's surface, its intensity increasing with time, (2) an elevating layer, that is a ground-based layer which weakens in rising, its intensity decreasing linearly with height, and (3) an elevated layer formed when a warm dry air mass is produced in the upper atmosphere; this layer grows with time. For each of these three types of layer, a ray-tracing program is used to compute the variations with time of the ray parameters and of the received signal level. As the statistics of the speed of layer formation and evolution are not precisely known, the time scale used in this study is somewhat arbitrary. However, this technique allows one to identify three typical fading patterns and to help interpret the physical mechanisms involved in the generation of multipath propagation. The frequency selective nature of the propagation channel bandwidth is then investigated over a 10.7-11.7 GHz in looking for the influence of each type of layer on the transfer function. Some experimental evidence relating to, and confirming, the predicted behavior values is also considered. Author

N95-20943# Communications Research Centre, Ottawa (Ontario).

DEVELOPMENT OF A FAST SAMPLING SYSTEM FOR ESTIMATION OF IMPULSE RESPONSES OF MOBILE RADIO CHANNELS

PIERRE MELANCON *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 7 p (SEE N95-20921 06-32) Jul. 1994
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This paper describes the features of measurement equipment developed to measure impulse response estimates of mobile radio channels in less than a ms per measurement. The development of such equipment was required to measure mobile radio channels in realistic operating scenarios, in a normal sized vehicle moving at typical speeds in different environments. Up to speeds of 70 km/hr, the measurement period is short enough to assume the equipment is measuring the same channel during the whole sampling interval. AT the transmitter end of the measurement system, a wideband signal (10 MHz) is produced by modulating a carrier frequency with a 511 bit pseudo random sequence at 5 Mb/s and transmitted through the radio channel. The received signal is down-converted to 70 MHz and demodulated by a complex demodulator. The quadrature baseband signals at the demodulator outputs are then filtered and sampled at high speed by two fast digitizers. During this process, the data are stored in large memory banks to allow a fast sampling rate during a long period of time. Data are transferred to laser disks for further processing in the laboratory. Impulse response of radio channels are estimated by performing a software correlation between a measurement system back to back reference and real time measurements. A minivan was modified to hold the receiver, digitizers, memory banks and the computer. A shaft encoder was attached to its rear left wheel to trigger measurements while moving. Features of the system are discussed along with the effects of data block length, signal to noise ratio, sampling rate, memory size and phase stability on the design of the measurement equipment. Finally, some measurement results are presented and discussed. Author

N95-20944# Institut National des Sciences Appliquees, Rennes (France). Lab. Composants et Systemes pour Telecommunications.

LINE-OF-SIGHT MULTIPATH PROPAGATION MEASUREMENTS AT 15 GHZ OVER 500 MHZ BANDWIDTH

M. TOUATI, G. ELZEIN, and J. CITERNE *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 10 p (SEE N95-20921 06-32) Jul. 1994

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An experimental wideband grazing radio link at 15 GHz has been set up on a 17.6 Km line-of-sight between Laille and Rennes to measure the variations of the propagation medium characteristics (attenuation and group delay versus frequency) due to meteorological effects. For this, a meteorological system was set up at the receiver station in order to measure the variations of the meteorological parameters (temperatures, pressure, rain precipitation, speed and direction of the wind). Consequently, the atmosphere refractive index is obtained. A particular interest is given to the occurrence of multipath fading in clear air caused by low-level layering in the troposphere. The collecting and recording of the propagation data (attenuation and group delay), from the MLA (microwave Link Analyzer), and that which relates to the meteorological characteristics, from the meteorological station, are executed using a computer program in a sequential manner. The channel impulse response, corresponding to each measured data, is calculated to deduce the number of rays detected and their different delays respectively. Besides this and using the meteorological parameters data acquired, the refractivity gradient is calculated in order to correlate the multipath fading occurrence to the meteorological parameters. Author

N95-20945# Centre de Recherches en Physique de l'Environnement, Velizy (France).

EXPERIMENTAL STUDY OF THE HELICOPTER-MOBILE RADIOELECTRICAL CHANNEL AND POSSIBLE EXTENSION TO THE SATELLITE-MOBILE CHANNEL

V. BLANCHETIERE-CIARLETTI, M. SYLVAIN, and P. LEMENN *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 12 p (SEE N95-20921 06-32) Jul. 1994

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The use of satellite seems to be an answer to the radioelectrical covering problem for the mobile communications, particularly in the low populated areas. Frequency bands at 1.5 and 2.5 GHz have been dedicated to these future services. Satellite-mobile links will be much more affected by propagation phenomena than the existing links between satellites and fixed stations. The reasons for that are twofold: The probable use of LEO (Low-Earth-Orbit) satellites instead of GEO; such satellites will have to be received at relatively low elevation to limit their number; the use of mobile communication terminals with small and non directive antennas that must work in various environments instead of terrestrian stations located at carefully chosen places and equipped with large diameter paraboloids. These propagation phenomena mainly consist in the fading of the signal level (shadowing of the link), and a frequency selective fading due to multipath propagation. The experience run by C.R.P.E. is aimed at a better understanding of the satellite-mobile propagation channel at fixed frequency as well as on a large band. In this paper, we discuss preliminary results from a series of propagation measurements performed (by lack of any experimental satellite) on an experimental radio link at 1.45 GHz on a of 20 MHz bandwidth between a helicopter flying at a height of 2 km and a mobile receiver. The whole experiment has been run in a rural environment in Brittany (France). In a first part, we illustrate the quality of the data collected during the experiment on a typical case study and give a possible physical interpretation of the observed phenomena. Then we present statistical results concerning the various characteristics (attenuation and delay spreads) of the propagation channel. Finally, we discuss the problem of using a helicopter (flying at a height of 2 km) as a substitute for a satellite at about 1000 km and try to estimate to what extent it is possible to use the data collected during this experiment to characterize the satellite-mobile channel. To do that, both the helicopter-mobile and the satellite-mobile propagation channels are simulated under the same environmental conditions. Author

N95-20946# Rome Lab., Hanscom AFB, MA.

COMPARATIVE STUDY OF C- AND K-BAND PROPAGATION MECHANISMS BEYOND THE HORIZON

UVE H. W. LAMMERS, RICHARD A. MARR, ROBERT K. CRANE (Oklahoma Univ., Norman, OK.), and MAGNUS WENNEMYR (Oklahoma Univ., Norman, OK.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 7 p (SEE N95-20921 06-32) Jul. 1994

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At intervals over a period of several years, we conducted simultaneous troposcatter measurements at frequencies of 4.95 and 15.73 GHz on a 161 km path in the northeastern United States. This ensured a fair comparison within a largely unspecified but identical propagation medium. Besides signal level, both systems yielded Doppler information on the propagation mechanism. In addition, the Ku-band system provided delay resolution by pseudorandom phase modulation. On the basis of these data, three primary propagation mechanisms could be identified: clear air turbulent scatter, rain scatter, and ducting. Criteria are given for the identification of these mechanisms along with the resulting received signal level and delay spread distributions under each propagation condition. Author

N95-20947# PTT Research, Leidschendam (Netherlands).

ANGLE DIVERSITY ON DIGITAL MICROWAVE LINKS: ANTENNA DESIGN AND EXPERIMENTAL RESULTS

D. BEAUFORT and L. P. LIGHART (Technische Hogeschool, Delft, Netherlands.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 7 p (SEE N95-20921 06-32) Jul. 1994

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PTT Research and Delft University of Technology examined the merits of angle diversity for multipath fading reduction on digital microwave links. A dual-polarized hybrid reflector array, suitable for beam switching in the vertical plane, was designed and produced. The antenna specifications were based on extensive propagation studies. The antenna was tested for two years on a 45 km hop in The Netherlands. It was found that switching between the antenna beams is superior to adaptive (maximum power) combining. Switching reduces the time that the Bit Error Ratio (BER) exceeds 10(exp -3) by a factor 27. Author

N95-20948# Naval Command, Control and Ocean Surveillance Center, San Diego, CA. Research, Development, Test and Evaluation Div.

MITIGATION OF EFFECTS OF MULTIPLE PATH NULLS AT SUPER-HIGH FREQUENCIES THROUGH DIVERSITY AND NETWORKING

N. DAVE *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 12 p (SEE N95-20921 06-32) Jul. 1994

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The goal of this work is to investigate the design issues implied by multipath effects for a high bandwidth communication network consisting of platforms in a Navy battle group. This communication network is designed to operate using super-high frequency (SHF) or ultra-high frequency (UHF) line-of-sight (LOS) propagation, and must be robust to variations in link quality due to platform motion or deletion, as well as to the effects of multipath propagation. High bandwidth in this context implies data rate in excess of 1.544 megabits per second (Mbps), known as 'TI' in the commercial world. Multipath nulls at the above frequencies can render links useless at certain ranges. In this work, we briefly discuss the well-known methods of height and frequency diversity, as well as a less frequently used but potentially powerful method of 'path diversity' through networking, to alleviate the ill effects of multipath nulls. The communication system configurations discussed are appropriate for expected platform separations in post-Cold War battle group scenarios, which envision most platforms within line-of-sight (LOS) distance from each other, i.e., separated by no more than about 20 nautical miles (nmi). Author

N95-20949# Phillips Lab., Hanscom AFB, MA. Ionospheric Effects Div.
MULTIPATH IMPACT ON GROUND-BASED GLOBAL POSITIONING SYSTEM RANGE MEASUREMENTS: ASPECTS OF MEASUREMENT, MODELING, AND MITIGATION
G. J. BISHOP and E. A. HOLLAND (Northwest Research Associates, Inc., Bellevue, WA.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 10 p (SEE N95-20921 06-32) Jul. 1994
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Multiple mechanisms propagation paths (multipath) can be the most important error source in ground-based Global Positioning System (GPS) measurement of range to the satellites. This multipath error, arising from a combination of the direct path and reflections from objects relatively close to the receiving antenna, can at times exceed the ionospheric delay error, which the two-frequency (1228 and 1575 MHz) GPS signal format is designed to measure and correct. GPS multipath can seriously degrade Differential GPS (DGPS) navigation, geodetic measurements, ionospheric monitoring, and other GPS applications, yet the source of the problem may not be evident without the use of specialized tests. Several techniques have been proposed to reduce the effects of GPS multipath; these include: improved receiver technology, specialized antenna designs, and various modeling or filtering approaches. This paper illustrates the nature of the two-frequency GPS multipath problem with measurement data from typical ground-based installations, exhibiting variation in multipath conditions, ranging from low to quite high for the varying geometries of the available satellite tracks. Leading mitigation techniques are reviewed, with emphasis on multipath modeling. A new simple modeling approach currently being studied by Phillips Laboratory is discussed. This technique takes advantage of the daily repetition of the GPS observation geometry from a ground station to create a 'multipath template' specific to each satellite pass, and reduce multipath effects on successive days. Data is presented showing significant improvement in a severe multipath environment and contrasting the effectiveness of this approach with all-sky modeling techniques. Mitigation techniques for GPS multipath show potential to enable GPS ground-based range and ionospheric measurement to greatly reduce errors at low elevation angles, leading to improved accuracy and wider coverage area capability. Author

N95-20950# Leeds Univ. (England). Satellite Communications Group.
IMPACT OF PROPAGATION MECHANISMS ON GLOBAL NAVIGATION SATELLITE SYSTEM PERFORMANCE
STUART RILEY, PETER DALY, and PETER RABY *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 11 p (SEE N95-20921 06-32) Jul. 1994
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Propagation mechanisms have a detrimental effect on the accuracy of satellite positioning systems such as GPS and GLONASS. The ionosphere at times of high activity will cause the greatest error due to the propagation medium. This paper describes a dual GPS/GLONASS receiver that is capable of measuring the ionospheric delay in the measured GLONASS pseudo ranges using both the code and carrier phases. This allows the pseudo ranges to be corrected for ionospheric delay and a more accurate position solution to be calculated. This paper describes the receiver architecture and fundamental accuracy; receiver measurement noise and calibration are also discussed before the impact of propagation mechanisms on the measurements are investigated. The measurement of the line of sight ionospheric delay, from a GLONASS satellite, is shown and compared with the GPS transmitted ionospheric model. An example of GLONASS P code navigation is given with and without correction for the ionosphere. Author

N95-20951# Boston Univ., MA. Center for Space Physics.
MITIGATION OF THE EFFECTS OF F LAYER REGULARITIES BY USING MULTIPLE PATHS
JULES AARONS *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 6 p (SEE N95-20921 06-32) Jul. 1994 Sponsored by ONR
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In recent military operations trans-ionospheric satellite to ground communications have been utilized in the equatorial region. One problem for the predominantly 250 MHz systems has been fading due to irregularities in the region within plus and minus 20 degrees of the magnetic equator. A similar problem has been encountered at high latitudes. For minimizing the effect of the fading, one might expect that radio links sufficiently separated in frequency and polarization would be effective in combating scintillation. Unfortunately frequency separations would have to be of the order of 100 MHz to obtain an adequate diversity improvement. The use of right and left circular polarization or of orthogonal linear polarizations is not effective. However, time diversity is a demonstrated procedure for overcoming scintillation but there is a loss of using coding or redundancy and a reluctance to complicate the system with modems. If the paths from a single satellite are sufficiently well separated then fading on two links is uncorrelated and diversity gain may be achieved. Unfortunately at equatorial latitudes separations of the order of a kilometer are involved. Another use of 'space diversity' can be effective. If the paths from two satellites with spacing between them are available and there is recognition that scintillation is causing the fading on the path to one satellite, then operators can utilize the path to a second satellite. For equatorial paths the operator must be alert as to the time development of irregularities and the dynamics of plume development. The differences in activity on the paths are due to two aspects of the irregularity plume i.e. the start time as the sunset moves westward and the spacing between plumes on the very active days. Examples of the time difference between the start of equatorial scintillations on one path versus that of another have been recorded in many sectors of the world. The results of these studies as applied to the problem of multiple paths will be shown. At high latitudes during moderate magnetic activity, it is possible to find paths that are not dominated by irregularities. However at auroral latitudes when a magnetic storm commences, the irregularity development moves equatorward with great rapidity and encompasses large areas. It is then difficult to find a path free of irregularities. Author

N95-20952# Maryland Univ., College Park, MD. Dept. of Physics.
ELECTROMAGNETIC WAVE REFLECTION FROM IRREGULAR PLASMA LAYERS
K. PAPADOPOULOS, R. SHORT (ARCO Power Technologies, Inc., Washington, DC.), and R. SHANNY (ARCO Power Technologies, Inc., Washington, DC.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 10 p (SEE N95-20921 06-32) Jul. 1994
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The general theory describing reflection of electro-magnetic waves from irregular reflectors was formulated by using path integral techniques. The general formulae reproduce the well known reflection coefficients for wave scattering from random rough surfaces derived by using Kirchhoff's theory or perturbation theory. The theory was used to determine the degradation of an OTH radar signal scattered from irregular Artificial Ionospheric Mirrors (AIM). The cases of density irregularities induced by fluctuations in the ambient neutral density and by fluctuations in the heater power were separately examined. Scaling laws and bounds for minimal signal loss were derived. Author

N95-20953# Phillips Lab., Hanscom AFB, MA. Ionospheric Physics Lab.
THE EFFECTS OF MULTIHOP HF PROPAGATION ON THE PERFORMANCE OF OTH BACKSCATTER RADARS
J. BUCHAU, S. DANDCKAR, G. S. SALES (Massachusetts Univ., Lowell, MA.), B. WEIJERS (Rome Lab., Hanscom AFB, MA.), and D. REYNOLDS (RADEX, Inc., Bedford, MA.) *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 7 p (SEE N95-20921 06-32) Jul. 1994
(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

Analysis of approximately one year's data from an operational OTH radar shows that equatorial clutter, originating in the ionosphere in regions up to 14,000 km from the radar, directly impacts the radar's performance. The radio wave propagation to these regions often involves from three or more ground hops depending on the radar's azimuth. These phenomena are important to all OTH radar systems in that great circle paths always cross the magnetic equator. The special data processing developed for this program uses both the long range (to 8000 nm) wideband 6 to 28 MHz) backscatter ionograms made routinely at selected azimuths and the radar's amplitude, range and Doppler data format, measuring the frequency of occurence, location and intensity of the clutter as a function of time and azimuth. These data indicate that intense ionospheric irregularities connected with the nighttime equatorial activity produce sufficient Doppler spread scattered energy that directly affects the performance of the radar. With the Parametric Ionospheric Model developed at the Phillips Laboratory and numerical ray tracing the specific interaction regions for the radar signal and the ionospheric irregularities are shown and an explanation for the observed temporal behavior is proposed. Several mechanisms for Doppler spreading of the clutter signal are also reviewed. Author

N95-20954# Paris-Sud Univ., Orsay (France). Lab. d'Electronique et de Technologie de l'Informatique.
TEMPORAL AND SPATIAL COMPORTMENT OF MULTIPLE PATHS IN IONOSPHERIC PROPAGATION IN OBLIQUE INCIDENCE: FRACTAL MEASURES OF PERTURBATIONS [COMPORTEMENT TEMPOREL ET SPATIAL DES TRAJETS MULTIPLES DANS LES PROPAGATIONS IONOSPHERIQUES EN INCIDENCE OBLIQUE MESURE FRACTALE DES PERTURBATIONS]
C. GOUTELARD, J. CARATORI, and L. BARTHES *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 17 p (SEE N95-20921 06-32) Jul. 1994 In FRENCH Original contains color illustrations
(AGARD-CP-543) Copyright Avail: CASI HC A03/MF A04

The electromagnetic wave propagation in the ionosphere is complex; the anisotropy and the inhomogeneity introducing multiple paths and the non stability of the Doppler effects. The ionospheric models usually used make it possible to account for the multiple paths and the Doppler shifts. According to these models, based on ray tracings, it appears that there is only one triplet (amplitude, Doppler, time travel) which makes it possible to plot simple diagrams. The experimental observation shows that, if one finds the signatures envisaged in the classical theory of the ray tracings for the signals of great amplitude, one observes, with systems of measurement of great sensitivity, signals of low amplitude which seem to translate the existence of diffuse propagations. The results of an oblique bistatic survey and of a backscattering study given in this presentation, show the appearance of effects of the second order. A method of characterization of these effects is proposed by the introduction of measurement of fractal dimensions of the functions of scattering, obtained by a method of high resolution spectral analysis. Transl. by CASI

N95-20955# Defence Research Agency, Malvern (England). Radio Propagation Exploitation Group.
DAMSON: A SYSTEM TO MEASURE MULTIPATH DISPERSION, DOPPLER SPREAD AND DOPPLER SHIFT ON MULTI-MECHANISM COMMUNICATIONS CHANNELS
NIGEL C. DAVIES and PAUL S. CANNON *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 6 p (SEE N95-20921 06-32) Jul. 1994
(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

The performance of communications equipment (especially data modems) designed to work over high frequency paths which can propagate by a number of different mechanisms is dependent on their ability to work with a wide range of signal to noise conditions and with varying degrees of frequency and time dispersion. The latter phenomena are a particular problem for systems operating over high latitude paths and yet there appears to be little available data documenting their severity or frequency of occurrence. DAMSON (Doppler And Multipath SOunding Network) is an oblique channel sounding system which has been developed by the UK Defence Research Agency (DRA) to measure a number of real-time channel parameters using low power pulse compression waveform transmissions. Extensive use is made of digital signal processing techniques. The system will allow signal time-of-flight, time dispersion (multipath dispersion), frequency dispersion (Doppler spread and Doppler shift) and signal strength to be measured over point-point communications paths. The DAMSON experiment is to be deployed to make measurements over a number of mid and high-latitude paths. This paper provides an introduction to the DAMSON system, its basic operation and measurement performance. The initial experiments to be conducted and the associated system deployment are presented. Author

N95-20956# Rennes Univ. (France). Lab. Radiocommunications.
IDENTIFICATION OF THE PROPAGATION MODES AND PATHS ON HF LINKS USING A GONIOPOLARIMETER [IDENTIFICATION DES MODES ET TRAJETS DE PROPAGATION SUR DES LIAISONS HF A L'AIDE D'UN GONIOPOLARIMETRE]
A. EDJEOU, L. BERTEL, and V. MASSOT *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 12 p (SEE N95-20921 06-32) Jul. 1994 In FRENCH
(AGARD-CP-543) Copyright Avail: CASI HC A03/MF A04

We present a system which is able to separate the propagation paths and also to identify the type of polarization of the modes. The studied links are between Monterfil (48 deg 05 N latitude, 2 deg W longitude) and all types of known location transmitters which work on carrier. The experimental analysis is performed using a 'goniopolarimeter' which is a device determining both the arrival angles (goniometrical function) and the type of polarization of the corresponding incoming skywaves. We apply a high resolution non linear frequency analysis associated with a reiterated method of filtering matched to this polarization. Author (revised)

N95-20957# Hull Univ. (England). Hull-Lancaster Communications Research Group.
GEOGRAPHICAL DIVERSITY COMBINING TO EXPLOIT MULTI-MECHANISM PROPAGATION
M. DARNELL and T. J. SPEIGHT *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 18 p (SEE N95-20921 06-32) Jul. 1994
Sponsored by UK Science and Engineering Research Council
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The paper introduces the principles of a new macroscopic diversity scheme employing maximum likelihood, symbol-level, diversity combining. The performance of the scheme is compared with that of other classical post-detector diversity combining methods. It is shown that the new scheme has a performance similar to the classical techniques; however, its complexity is significantly lower. The application of macroscopic diversity in the HF band is then described, and the results of practical on-air trials presented. Author

N95-20958# Leeds Univ. (England). Dept. of Electronic and Electrical Engineering.
SUPERRESOLUTION DIRECTION FINDING ALGORITHMS FOR THE CHARACTERISATION OF MULTI-MODED HF SIGNALS
M. A. ZATMAN and H. J. STRANGEWAYS *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 10 p (SEE N95-20921 06-32) Jul. 1994
(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

In this work three superresolution direction finding algorithms for use with arbitrary array geometries are described, all of which are capable of dealing with coherent signals, as typically found in the multi-path environment. DOSE is a quick single snapshot algorithm developed by the authors which operates on the received data vector. The IMP and Maximum Likelihood (ML) algorithms are used to process time averaged data covariance matrices. All three algorithms attempt in different ways to find a multi-dimensional solution to the inverse problem of direction finding. It is shown that calibration of arrays of identical elements is simplified by the use of these multi-dimensional algorithms when compared to 1 dimensional methods such as MUSIC. A common methodology for the implementation of these multi-dimensional algorithms is presented, and a quick method of implementing the ML algorithm and determining the number of signals present is described. Author

N95-20959# Thomson-CSF, Gennevilliers (France).
MEASUREMENTS OF ANGLES OF ELEVATION OF HF BY A HIGH RESOLUTION METHOD USING POLARIZATION DIVERSITY [MESURES D'ANGLES D'ELEVATION EN HF PAR UNE METHODE HAUTE RESOLUTION UTILISANT LA DIVERSITE DE POLARISATION]
CEDRIC DEMEURE, ANNE FERREOL, and JEAN-LUC ROGIER *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 9 p (SEE N95-20921 06-32) Jul. 1994 In FRENCH
(Contract(s)/Grant(s): DRET-90-34-473)
(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

In this paper, we present the use of high resolution techniques and polarization diversity in order to analyze HF links in ionospheric propagation, links which are characterized in general by the presence of several modes of propagation giving rise to several incident waves with the reception. These modes are strongly correlated and can have very different polarizations. The high resolution techniques have the capacity to simultaneously measure several incident waves present in a given frequency channel of analysis, and are thus adapted particularly to the situation of jamming where a frequency and/or temporal separation is no longer possible. The use of a network with polarization diversity allows, beyond obtaining certain parameters of polarization, an increase in the resolution of the methods considered, because of the difference in polarization of the modes. A better knowledge of the phenomenon of propagation waves in this medium is the anticipated result of the application of these techniques. For a given connection and at first approximation (one neglects the effects due to the 'tilt', or the rebound on a tilted ground), the modes arrive under the same azimuth with different angles of elevation. In the experiment described in this paper, the measurement of the angles of elevation is made by supposing a knowledge of azimuth. Thus we use a linear network and let us direct it in order to obtain good performances for the estimate of the angles of elevation. The method high resolution with diversity of polarization used is method MUSIC adapted in order to take account of the use of sensors having gains different according to polarization from the received wave. Transl. by CASI

N95-20960# Forschungsinstitut fuer Hochfrequenzphysik, Werthhoven (Germany).
MEASUREMENTS OF RADAR BACKSCATTER FROM THE OCEAN SURFACE AT 94 GHZ AS A FUNCTION OF WIND SPEED, DIRECTION AND THE MODULATION BY THE OCEAN WAVES DURING THE SAXON-FPN EXPERIMENT
HANS-HELLMUTH FUCHS *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 7 p (SEE N95-20921 06-32) Jul. 1994
(AGARD-CP-543) Copyright Avail: CASI HC A02/MF A04

As part of the joint German/US SAXON-FPN remote sensing experiment a series of mm-wave radar backscatter measurements were carried out in the German Bight of the North Sea in November 1990, 1991 and August 1992. The dependence of the reflectivity sigma(sup o) on wind speed and direction was determined by means of a 94 GHz (W-band) radar mounted on the German Research Platform North Sea (FPN). The radar backscattering measurements were performed at an incidence angle of 45 deg and at azimuth angles relative to the wind direction ranging from upwind to crosswind. Based on the data evaluation of the three measurement periods values for the wind speed exponent gamma defined by an empirical relation between the reflectivity sigma(sup o) at vertical polarization and the windspeed U measured at a height of 46 m above mean sea level at the FPN were obtained. The values of gamma range between 2.33 and 2.50 depending on wind direction and the wave spectrum. This result shows that the wind speed exponent at W-band is higher than those at X-, Ku- and Ka-band indicating that either an enhanced generation of higher amplitudes of short waves in the millimeter range or other processes exist like specular scattering from facets reinforcing the backscatter cross section. Author

N95-20961# Centre National d'Etudes des Telecommunications, Lannion (France). Lab. PTI.
SOUNDER CALIBRATION WITH BACKSCATTERING FROM LOSQUET ISLAND IN THE PRESENCE OF MULTIPATHS [CALIBRATION DU SONDEUR A RETRODIFFUSION DE L'ILE LOSQUET EN PRESENCE DE MULTI-TRAJETS]
F. GAUTHIER, J. Y. LESAOUT, and R. FLEURY *In* AGARD, Multiple Mechanism Propagation Paths (MMPPs): Their Characterisation and Influence on System Design 12 p (SEE N95-20921 06-32) Jul. 1994 In FRENCH
(AGARD-CP-543) Copyright Avail: CASI HC A03/MF A04

The precise localization of the areas of the ionosphere by HF forward-scatter radars depends on the parameters characteristic of the propagation at the time of the survey, and often requires the use of calibration techniques. To gauge the data of the sounder with backscattering data from the Losquet Island, the National Center of Studies of Telecommunications (CNET) implemented a HF mobile monofrequency responder radar. This paper presents the results of surveys obtained in 'scanning of site' mode with this responder and established to approximately 1000 km the Losquet Island; these data are used to calculate the position of the responder. It is shown that the multipaths are the primary source of the statistical error of localization in radial distance and that the use of simple methods of treatment allows the reduction of this error. Transl. by CASI

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ELECTRONICS AND ELECTRICAL ENGINEERING

Includes test equipment and maintainability; components, e.g., tunnel diodes and transistors; microminiaturization; and integrated circuitry.

N95-20639# Bell Telephone Labs., Inc., Whippany, NJ.
PACKAGING THE MAMA MODULE
J. DENNIS SEALS *In* AGARD, Advanced Packaging Concepts for Digital Avionics 7 p (SEE N95-20631 06-06) Oct. 1994
Prepared in cooperation with Army Night Vision Labs
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

The MAMA (Mixed Arithmetic, Multiprocessing Array) module is being developed to evaluate new packaging technologies and processing paradigms for advanced military processing systems. The architecture supports a tight mix of signal, data,and I/O processing at GFLOP throughput rates. It is fabricated using only commercial-on-the-sehlf (COTS) chips and will provide a high level of durability. Its attributes are largely the result of two new interconnection and packaging technologies. Chip-in-board packaging is used to reduce local x-y communication delays and solder joints, while significantly improving board-level packaging density. A unique 3-D interconnection technology called a cross-over cell has been developed to reduce board-to-board communication delays, drive power, glue logic, and card-edge pin-outs. These technologies enable true 3-D structures that are form, fit and connector compatible with conventional line-replacable

modules. The module's design rational, packaging technology, and basic architecture will be presented in this paper. Author

N95-20640# Army Research Lab., Fort Monmouth, NJ.
THE DEMISE OF PLASTIC ENCAPSULATED MICROCIRCUIT MYTHS
E. B. HAKIM, R. K. AGARWAL (Delco Electronics, Kokomo, IN.), and M. PECHT (Maryland Univ., College Park, MD.) *In* AGARD, Advanced Packaging Concepts for Digital Avionics 7 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

Production of microelectronic devices encapsulated in solid, molded plastic packages has rapidly increased since the early 1980's. Today, millions of plastic-encapsulated devices are produced daily. On the other hand, only a few million hermetic (cavity) packages are produced per year. Reasons for the increased use of plastic-encapsulated packages include cost, availability, size, weight, quality, and reliability. Markets taking advantage of this technology range from computers and telecommunications to automotive uses. Yet, several industries, the military in particular, will not accept such devices. One reason for this reluctance to use the best available commercial parts is a perceived risk of poor reliability, derived from antiquated military specifications, standards, and handbooks; other common justifications cite differing environments; inadequate screens; inadequate test data, and required government audits of suppliers' processes. This paper describes failure mechanisms associated with plastic encapsulation and their elimination. It provides data indicating the relative reliability of cavity and solid-encapsulated packaging, and presents possible approaches to assuring quality and reliability in the procuring and applying this successful commercial technology. Author

N95-20642# Naval Air Warfare Center, Indianapolis, IN. Standard Hardware Acquisition and Reliabilty Program.
ADVANCED STANDARD ELECTRONIC MODULES FORMAT-E (SEM-E) PROCESSES FOR RAPID PROTOTYPING
ANTHONY HAWKINS *In* AGARD, Advanced Packaging Concepts for Digital Avionics 11 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

The objective of the 'Advanced SEM Processes' effort is to simplify the development and qualification processes and reduce the related process times and costs from the current way of doing business. Advanced technology developments and qualifications typically are completed in three to five years from conception. The Standard Hardware Acquisition and Reliability Program (SHARP) is working in conjunction with the Advanced Research Project Agency (ARPA) Application Specific Electronic Modules (ASEM) effort, Raytheon and the Electronics Manufacturing Producibility Facility (EMPF) Manufacturing Technology efforts to define new processes for development and qualification that leverage commercial and military technology in applying 'MultiChip Modules' (MCM's) to Standard Electronic Module format E (SEM-E) packaging. These processes are anticipated to have applicability to the development and qualification of SEM-E packaging, using multiple state of the art technologies in addition to MCM's. The primary objective is to reduce the current cycle time from three - five years to twelve months and costs from $500,000 - $1,000,000 to $100,00 - $250,000, therefore providing a baseline for standardizing electronics hardware acquisition processes into the twenty first century and beyond. Author

N95-20644# Rome Lab., Griffiss AFB, NY.
ASSURING KNOWN GOOD DIE (KGD) FOR RELIABLE, COST EFFECTIVE MCMS
DANIEL E. DASKIEWICH *In* AGARD, Advanced Packaging Concepts for Digital Avionics 7 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

A key requirement for achieving high yield multichip modules (MCM's) is assuring that the individual dice are known good devices (KGD). A KGD is defined as a bare die available at the same quality and reliability as the equivalent single chip packaged parts. Integrated circuits (IC's) that are Known Good will function over a specified temperature range, are compatible with the MCM approach utilized, and contain no short-term or long-term reliability hazards. The application of reliability and testability techniques at all levels of MCM development, particularly at the chip level, will maximize MCM yield. Today's testing and qualification requirements, defined by MIL-STD-883 Methods 5008 and 2010, are not capable of assuring KGD as defined above. The development of cost effective requirements for achieving 99.9 percent yields poses a challenge which requires new and novel approaches and better methods for bare die testing, wafer level burn-in, tape automated bonding (TAB), temporary packaging, at-speed device testing at the wafer, die, and MCM level. Also of great importance are the methods for built-in self test (BIST), built-in test (BIT), and boundary scan. New standards in very large scale integration (VLSI) device testing must be developed in order for MCM's to be reliable and economical. Rome Laboratory (RL) has funded a program to address and develop these requirements. The objectives of the RL program are to: research and evaluate current and proposed burn-in, electrical and interconnect test techniques for assuring known good VLSI circuits at wafer and die level; and evaluate various methods of incorporating testability features which will decrease test time and cost. In addition, MCM-level reliability and performance assessment procedures will be evaluated to determine appropriate testing concepts and procedures that will assure the procurement of reliable, cost effective MCM's for DOD/NASA applications. The program consists of two phases: Phase One will be a study phase to evaluate, analyze, trade-off, and select best techniques for test and burn-in of wafers, bare die and MCM's. Phase Two will be a demonstration of a cost effective procedure for assuring high quality/reliable production of MCM's based on the KGD methods developed in Phase One. Author

N95-20645# Lucas Electronics, Birmingham (England).
THE DESIGN AND MANUFACTURING DEVELOPMENT OF AN ACTIVE SILICON SUBSTRATE MCM
M. G. ROUGHTON and L. WAITE *In* AGARD, Advanced Packaging Concepts for Digital Avionics 7 p (SEE N95-20631 06-06) Oct. 1994 Sponsored by DTI
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

The demand for engine control systems with reduced weight, size and cost, increased integration, improved reliability and higher temperature operation drives the system designer to the use of advanced hybrid assembly technologies. This paper describes the design and manufacturing development of a silicon based 'D' type multichip module, MCM, containing an active substrate of memory. This CPU module is one of the building blocks for a range of generic engine control systems. The active substrate approach potentially gives higher packing density than wafer scale due to its 3D configuration. The active substrate comprises 12 SRAM 128K x 8 bit of diffused memory arranged in groups of three. The design is organized so that a 'memory manager' ASIC selects pages of good memory from the substrate die thus obtaining the best possible yield. A single wafer contains 4 silicon hybrid substrates, each approximately 40mm sq, which will be processed before separating into discrete circuits. The MCM structure is comprised of four aluminium metallization layers with benzocyclobutene, BCB, as the dielectric. Approximately 16 other devices including a processor, the 'memory manager' ASIC, a Processor Support ASIC and EDPROM, plus resistor network chips and decoupling capacitors will be added to the silicon substrate using adhesive and wire bond interconnection. The 'memory manager' ASIC tests the RAM on power-up, reject areas of bad memory and configures the good areas such that a continuous block of functional RAM is available to the processor. The RAM is configured as a 16 bit wide with both 16 bit and 8 bit read/write accesses being supported. The total module is to be assembled in a high temperature co-fired ceramic package with 200 I/O. After test and any rework that may be necessary the package will be sealed with a Kovar lid ready for final test. Author

N95-20651# Naval Air Warfare Center, Warminster, PA. Aircraft Div.
A TECHNIQUE FOR INCREASING THE BANDWIDTH OF HIGH PERFORMANCE ELECTRICAL BACKPLANES
W. ROSEN, S. RAJAN, V. GERSHMAN, and M. SHADARAM (Texas Univ., El Paso, TX.) *In* AGARD, Advanced Packaging Concepts for Digital Avionics 4 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A01/MF A03

This paper presents an active matching technique for extending the data rates of electrical backplane interconnects into the gigabit per second (Gb/s) range. In the active matching technique an active bandpass amplifier is used to drive the backplane

transmission lines. The gain characteristic of the amplifier is designed to be complementary to that of the transmission line and connectors using standard microwave matching techniques. This technique is suitable for use with conventional stripline and microstrip backplanes as well as newer microcoaxial cables. Using this technique, backplanes operating at serial data rates in excess of 4 Gb/s have been demonstrated and speeds of 10 Gb/s may be possible. These results suggest that electrical backplanes may be competitive with optical backplanes in speed and superior to them in cost, power consumption, and complexity. Author

N95-20653# GEC-Marconi Materials Technology, Towcester (England).
HIGH PERFORMANCE BACKPLANE COMPONENTS FOR MODULAR AVIONICS
C. J. GROVES-KIRKBY, M. J. GOODWIN, J. P. HALL, G. GLYNN, J. HANKEY, M. D. SALIK, R. C. GOODFELLOW, and D. J. JIBB (GEC-Marconi Avionics Ltd., Chelmsford, England.) *In* AGARD, Advanced Packaging Concepts for Digital Avionics 6 p (SEE N95-20631 06-06) Oct. 1994
(Contract(s)/Grant(s): ESPRIT 3 PROJ. 6276)
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03
The design and development of optoelectronic transceiver and optical pathway components for application in a modular avionics backplane demonstrator system are described and initial performance results are presented. Author

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FLUID MECHANICS AND HEAT TRANSFER

Includes boundary layers; hydrodynamics; fluidics; mass transfer; and ablation cooling.

N92-27450# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
CFD TECHNIQUES FOR PROPULSION APPLICATIONS [LES TECHNIQUES DE L'AERODYNAMIQUE NUMERIQUE POUR LES APPLICATIONS AUX PROPULSEURS]
Feb. 1992 588 p In ENGLISH and FRENCH The 77th symposium was held in San Antonio, TX, 27-31 May 1991 Original contains color illustrations
(AGARD-CP-510; ISBN-92-835-0659-6; AD-A253647) Copyright Avail: CASI HC A25/MF A06
The symposium was composed of the following sessions: turbomachinery computations and validations; flow in ducts, intakes, and nozzles; and reacting flows. Forty papers were presented, and they covered full 3-D code validation and numerical techniques; multidimensional reacting flow; and unsteady viscous flow for the entire spectrum of propulsion system components. The capabilities of the various numerical techniques were assessed and significant new developments were identified. The technical evaluation spells out where progress has been made and concludes that the present state of the art has almost reached the level necessary to tackle the comprehensive topic of computational fluid dynamics (CFD) validation for propulsion. For individual titles, see N92-27451 through N92-27490.

N92-27451# Technische Hochschule, Aachen (Germany). Aerodynamisches Inst.
COMPUTATIONAL TECHNIQUES FOR SOLVING THE NAVIER-STOKES EQUATIONS
D. HAENEL *In* AGARD, CFD Techniques for Propulsion Applications 26 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
Computational techniques for the solution of the Navier-Stokes equations of compressible flows are addressed. In the first section, the governing equations and their most important approximations are described. A review of computational techniques encloses grid arrangement, conservative discretization, numerical flux formulations, and different methods of solution inclusive multigrid methods. In the last section, the influence of the numerical discretization on the accuracy of Navier-Stokes solutions is briefly discussed. Author

N92-27452# Royal Aerospace Establishment, Farnborough (England). Propulsion Dept.
APPLICATION OF S1BYL2 TO THE AGARD WG18 COMPRESSOR TEST CASES
W. J. CALVERT *In* AGARD, CFD Techniques for Propulsion Applications 16 p (SEE N92-27450 18-34) Feb. 1992 Previously announced as N91-30147
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
S1BYL2 is an inviscid-viscous blade-to-blade method for calculating the detailed aerodynamics and overall performance of compressor blades. It may be applied either on its own to predict the flow for individual blade sections, such as the midspan of a linear cascade, or in conjunction with a throughflow calculation to predict the performance of a complete axial compressor. New predictions for the V2 and ARL SL19 cascades and for the high speed compressor cases are presented. It is hoped that this will be one of many sets of calculations for these cases, so that an improved understanding of each case may be obtained, together with an appreciation of the strengths and weaknesses of different computational approaches. Author

N92-27453# Virginia Polytechnic Inst. and State Univ., Blacksburg, VA. Dept. of Mechanical Engineering.
A COMPUTATIONAL STUDY OF TIP LEAKAGE FLOW AND LOSSES IN A LINEAR TURBINE CASCADE
JOHN MOORE and JOAN G. MOORE *In* AGARD, CFD Techniques for Propulsion Applications 12 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
A computational study of 3-D flow in the Virginia Polytechnic Institute and State University (VPI&SU) tip leakage turbine cascade is used to show the level of modeling attainable now. Results for the overall flow development are compared with measurements of flow and losses at the exit of the tip leakage gap and downstream of the blade row. Mechanisms for the additional loss due to tip leakage are discussed. Consideration is given to areas where the modeling of fine scale flow structure may be improved. These include the flow in the tip clearance gap, flow in the tip leakage vortex, and flow separation at the trailing edge. Author

N92-27454# Genoa Univ., Genoa (Italy). Dipartimento di Ingegneria Energetica.
TIME-MARCHING METHODS FOR SECONDARY FLOW ANALYSIS IN CURVED DUCTS
M. MARINI, A. MASSARDO, and A. SATTA *In* AGARD, CFD Techniques for Propulsion Applications 7 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A02/MF A06
Compressible rotational flows in curved ducts due to inlet total pressure gradients are analyzed. Two different time-marching methods are briefly presented and utilized for the analysis of the development of 3-D flows. The former is a finite volume explicit method, and the latter is a finite difference implicit method. These methods are successfully compared to each other and with other methods. A first analysis of secondary flows concerning constant section curved ducts with a curvature of 90 degrees is performed. Author

N92-27455# Wright Lab., Wright-Patterson AFB, OH.
TURBINE INTERNAL FLUID FLOW ANALYSIS AND STOKES' HYPOTHESIS
ROBERT E. GRAY and WILLIAM A. TROHA *In* AGARD, CFD Techniques for Propulsion Applications 14 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
Two dimensional Navier-Stokes solvers are beginning to appear for the purpose of analyzing fluid flow and heat transfer phenomena in turbomachinery. It is often assumed that the Navier-Stokes equations represent the ultimate in precision and generality possible when the fluid is modeled as a continuum. Therefore, the advent of the high-speed computer has spawned a number of finite differencing schemes aimed at solving these equations for steady and unsteady flows, both internal and external. In the case of compressible flows with heat transfer, some of these schemes have had questionable success in the approximation of experimental data despite use of accepted solution techniques and reasonable care in maintaining rigor in boundary conditions. Stoke's hypothesis, with its implication of zero bulk viscosity for a

viscous fluid, may have a bearing on some of these anomalies. Two viscous, compressible flow phenomena, in the form of expansion waves, for which the level of irreversibility implied by Stoke's hypothesis appears to be suspect. Author

N92-27456# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. fuer Antriebstechnik.

COMPUTATION OF 3D-VISCOUS FLOW AND HEAT TRANSFER FOR THE APPLICATION TO FILM COOLED GAS TURBINE BLADES

THORSTEN VOGEL *In* AGARD, CFD Techniques for Propulsion Applications 12 p (SEE N92-27450 18-34) Feb. 1992

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The mechanism of film cooling and heat transfer on gas turbine blades and end walls is theoretically investigated by simultaneously solving the 3-D Navier-Stokes equations for the flow field and the 3-D heat conduction equation for the cooled blade. The coupling of flow calculation and heat conduction calculation in the turbine blades supplies the wall temperatures and heat fluxes at the blade surfaces. These have to be taken from measurements if a traditional boundary layer approach is used for calculating the corresponding heat transfer coefficients. Heat transfer coefficients and film cooling efficiencies resulting from the 3-D solution are presented. Additionally, a comparison between measured and calculated data is shown. Author

N92-27457# Durham Univ. (England). School of Engineering and Applied Science.

EXPERIMENTAL VERIFICATION OF A 3D TURBULENT FLOW CALCULATION IN AN AXIAL TURBINE CASCADE

J. G. E. CLEAK (Durham Univ. (England).), D. G. GREGORY-SMITH (Durham Univ. (England).), and N. T. BIRCH (Rolls-Royce Ltd., Derby, England) *In* AGARD, CFD Techniques for Propulsion Applications 15 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by Rolls-Royce Ltd. and Science Research Council

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A Navier-Stokes computer code was used for the calculation of the 3-D secondary flow in a cascade of axial turbine blades. A comparison is made with experiment of the results of various applications of a mixing length model within the code. The results are compared on the basis of mean flow data and also turbulent Reynolds shear stresses. Substantial grid independence was obtained with a grid of 20,000 points; further grid refinement had a significant effect only on midspan loss. Large variations in the results were obtained with laminar flow being imposed for up to 80 percent of the axial chord away from the end wall. The high turbulence activity in the vortex core was not predicted; the flow close to the endwall and blade surfaces appeared to dominate the calculated flow. The need for higher order turbulence modeling is indicated, but probably of greater importance is the accurate prediction of transition. Author

N92-27458*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

A MATHEMATICAL CONSTRAINT PLACED UPON INTER-BLADE ROW BOUNDARY CONDITIONS USED IN THE SIMULATION OF MULTISTAGE TURBOMACHINERY FLOWS

J. J. ADAMCZYK *In* AGARD, CFD Techniques for Propulsion Applications 8 p (SEE N92-27450 18-34) Feb. 1992

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A number of researchers have suggested using an inter-blade row boundary condition to extend isolated blade row flow solvers to multiple blade row configurations. This suggestion is worth consideration for it appears to result in codes that are computationally more efficient than those based on other schemes that were suggested to accomplish the same task. The work is concerned with the development of a mathematical constraint which this boundary condition must satisfy to insure the proper transfer of momentum and vorticity across the plane. Using experimental data, the work quantifies the error in the time-averaged vorticity field which results from simply requiring continuity across the boundary plane of the momentum based on the time-averaged velocity fields associated with a multiple blade row configuration. Author

N92-27459*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

A CRITICAL EVALUATION OF A THREE-DIMENSIONAL NAVIER-STOKES METHOD AS A TOOL TO CALCULATE TRANSONIC FLOWS INSIDE A LOW-ASPECT-RATIO COMPRESSOR

CHUNILL HAH and STEVEN L. PUTERBAUGH (Air Force Systems Command, Wright-Patterson AFB, OH.) *In* AGARD, CFD Techniques for Propulsion Applications 14 p (SEE N92-27450 18-34) Feb. 1992 Original contains color illustrations

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A numerical study to evaluate a three-dimensional Navier-Stokes method as a tool to predict the detailed flow field inside a low-aspect-ratio compressor at various operating conditions was conducted. The details of the flow structure inside a low aspect ratio compressor (three-dimensional shock structure, shock-boundary layer interaction, and tip leakage vortex) and the overall aerodynamic performance at design and off-design conditions are numerically analyzed and the results are compared with the available experimental data. The flow field inside a state-of-the-art transonic compressor is used for the purpose of the evaluation. D.R.D.

N92-27460# Paris VI Univ. (France).

ON THE COMPUTATION OF UNSTEADY TURBOMACHINERY FLOWS. PART 1: EULER EQUATIONS IN VIBRATING CASCADES

GEORG A. GEROLYMOS *In* AGARD, CFD Techniques for Propulsion Applications 19 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by SNECMA

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A methodology is presented for unsteady flow analysis in vibrating transonic compressor cascades, using Euler equations. After a brief discussion of the problem, the numerical algorithm is presented, for the 3-D case, with particular emphasis on grid displacement procedures, slip surface fitting, boundary conditions, and their effect on computational results. Chorochronic flow periodicity and model superposition are briefly discussed. Several results from realistic aircraft engine turbomachinery configurations are presented. The lack of, and urgent need for 3-D experimental data combining unsteady pressure measurements and vibrating mode shapes are stressed. The methods are then validated through comparison with time linearized flat plate cascade theory (analytical) and experimental data from annular and linear cascades. A method for computing the aeromechanical coupling is presented. Finally, a discussion is presented of viscous effects. Author

N92-27465# Electricite de France, Chatou (France). Dept. Machines.

CALCULATION BY THE FINITE ELEMENT METHOD OF 3-D TURBULENT FLOW IN A CENTRIFUGAL PUMP [CALCUL PAR ELEMENTS FINIS DE L'ECOULEMENT 3D TURBULENT DANS UNE POMPE CENTRIFUGE]

J. F. COMBES *In* AGARD, CFD Techniques for Propulsion Applications 10 p (SEE N92-27450 18-34) Feb. 1992 In FRENCH; ENGLISH summary

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In order to solve industrial flow problems in complex geometries, a finite element code, N3S, was developed. It allows the computation of a wide variety of 2-D or 3-D unsteady incompressible flows, by solving the Reynolds averaged Navier-Stokes equations together with a k-epsilon turbulence model. Some recent developments of this code concern turbomachinery flows, where one has to take into account periodic boundary conditions, as well as Coriolis and centrifugal forces. The numerical treatment is based on a fractional step method: at each time step, an advection step is solved successively by means of a characteristic method; a diffusion step for the scalar terms; and finally, a Generalized Stokes Problem by using a preconditioned Uzawa algorithm. The space discretization uses a standard Galerkin finite element method with a mixed formulation for the velocity and pressure. An application is presented of this code to the flow inside a centrifugal pump which was extensively tested on several air and water test rigs, and for which many quasi-3-D or Euler calculations were reported. The present N3S calculation is made on a finite element mesh comprising about 28000 tetrahedrons and 43000 nodes. Author

N92-27467*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
VISCOUS THREE-DIMENSIONAL CALCULATIONS OF TRANSONIC FAN PERFORMANCE
RODRICK V. CHIMA *In* AGARD, CFD Techniques for Propulsion Applications 19 p (SEE N92-27450 18-34) Feb. 1992 Previously announced as N92-17346
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A 3-D flow analysis code was used to compute the design speed operating line of a transonic fan rotor, and the results were compared with experimental data. The code is an explicit finite difference code with an algebraic turbulence model. The transonic fan, called Rotor 67, was tested experimentally at NASA Lewis conventional aerodynamic probes and with user anemometry and was included as one of the AGARD test cases for the computation of internal flows. The experimental data are described. Maps of total pressure ratio and adiabatic efficiency vs mass flow were computed and are compared with the experimental maps, with good agreement. Detailed comparisons between calculations and experiment are made at two operating points, one near peak efficiency and the other near stall. Blade-to-blade contour plots are used to show the shock structure. Comparisons of circumferentially integrated flow quantities downstream of the rotor show spanwise distributions of several aerodynamic parameters. Calculated Mach number distributions are compared with laser anemometer data within the blade row and the wake to quantify the accuracy of the calculations. Particle traces are used to show the nature of secondary flow. Author

N92-27468# United Technologies Optical Systems, Inc., West Palm Beach, FL. Theoretical and Computational Fluid Dynamics Group.
NAVIER-STOKES ANALYSIS OF TURBINE BLADE HEAT TRANSFER AND PERFORMANCE
DANIEL J. DORNEY and ROGER L. DAVIS *In* AGARD, CFD Techniques for Propulsion Applications 12 p (SEE N92-27450 18-34) Feb. 1992
(Contract(s)/Grant(s): N00140-88-C-0677)
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
A three dimensional Navier-Stokes analysis of heat transfer and aerodynamic performance is presented for a low speed linear turbine cascade. The numerical approach used consists of an alternate direction, implicit, approximate factorization, time marching technique. An objective was to establish the computational grid density requirements necessary to accurately predict blade surface and endwall heat transfer, as well as the exit plane aerodynamic total pressure loss and flow angle distributions. Also, a study was performed to determine a viable implementation strategy for the 3-D modeling of transition and turbulence in the turbine blade passage. Results are presented which show that the present procedure can accurately predict 3-D turbine blade heat transfer as well as the absolute level and spanwise distribution of aerodynamic performance quantities. Author

N92-27470# National Technical Univ., Athens (Greece). Lab. of Thermal Turbomachines.
UNSTEADY EULER CALCULATIONS IN 3D INTERNAL AERODYNAMICS
M. HADZIDAKIS, F. KARAGIANNIS, P. CHAVIAROPOULOS, and K. D. PAPAILIOU *In* AGARD, CFD Techniques for Propulsion Applications 8 p (SEE N92-27450 18-34) Feb. 1992
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An implicit finite difference algorithm is presented which solves the unsteady Euler equations in three dimensional ducts. The Helmholtz decomposition is examined of the unsteady velocity field into a potential and a rotational part. The geometry does not change with time, thus the unsteady nature of the flow is due to the time dependent inflow and outflow boundary conditions. The flow at the inlet is supposed to be rotational. Vorticity is introduced by means of velocity, total enthalpy, or even entropy profile slope. The results cover a wide range of reduced frequencies in the subsonic flow regime. Author

N92-27471# Rolls-Royce Ltd., Derby (England).
THE APPLICATION OF A NAVIER-STOKES CFD METHOD TO CIVIL ENGINE INTAKE FLOWS
N. T. BIRCH (Rolls-Royce Ltd., Derby (England).), E. H. KITCHEN (Rolls-Royce Ltd., Derby (England).), and R. J. G. NORTON (Rolls-Royce, Inc., Atlanta, GA.) *In* AGARD, CFD Techniques for Propulsion Applications 10 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by Ministry of Defence
(AGARD-CP-510) Copyright Avail: CASI HC A02/MF A06
Three-dimensional flows around civil engine intakes were calculated by a Navier-Stokes method. The full Reynolds-averaged Navier-Stokes equations for viscous flow are solved by an explicit time-marching cell-centered finite-volume algorithm. To ensure numerical stability, Jameson's formulation of fourth-order and second-order smoothing is used. Second-order smoothing is switched on only in regions of strong pressure gradient such as shocks. The flow may be laminar or turbulent; turbulence is treated by a mixing-length eddy viscosity model. The algorithm is applied on a body-fitted C-type computational grid. Author

N92-27472# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.
CFD CONTRIBUTIONS DURING HYPERSONIC AIRPLANE INTAKE DESIGN
N. C. BISSINGER and A. EBERLE *In* AGARD, CFD Techniques for Propulsion Applications 24 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by BMFT
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
Above certain Mach numbers, flows in wind tunnels can no longer fully simulate the actual flow physics. In the design of optimal propulsion systems, which are capable of economically propelling aircraft to hypersonic Mach numbers, understanding of the 'real' flow is mandatory. This paper will address recently developed numerical elements of an advanced CFD code in terms of computational speed and accuracy. Results will be presented of several calculations performed to gain insight into the flow in hypersonic intakes. Author

N92-27473# Middle East Technical Univ., Ankara (Turkey).
THREE DIMENSIONAL SOLUTION OF INTERNAL FLOWS USING A CELL VERTEX FINITE VOLUME METHOD
ERDAL OKTAY, I. SINAN AKMANDOR, and AHMET S. UCER *In* AGARD, CFD Techniques for Propulsion Applications 14 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06
The numerical solutions for internal three-dimensional Euler flows were obtained by using a cell-vertex finite volume method. The solver which was developed, was applied to a wide range of subsonic, transonic, and supersonic test cases, among which, are the Ni-bump channel, the supersonic wedge cascade, and the 90 degree bend channel. A second order accurate, one-step Lax-Wendroff scheme was used to solve the unsteady equations, discretized in strong conservation form. Characteristic boundary conditions were used along with appropriate artificial viscosity and smoothing models. The results illustrate the established flow symmetry in a subsonic Ni-bump channel, the shock - boundary interaction in transonic and supersonic Ni-channels and wedge cascade, and finally, the secondary flow within a 90 degree bend channel. Despite the wide range in the Mach number and the diversity of flow geometries which were tested, close agreement was obtained with available analytical and numerical results associated with these test cases. Author

N92-27474# University Coll. of Swansea (Wales). Dept. of Civil Engineering.
NUMERICAL REPRESENTATION OF HEAT TRANSFER INTO TURBINE BLADE COOLING DUCTS
C. TAYLOR, J. Y. XIA, J. O. MEDWELL, and W. D. MORRIS *In* AGARD, CFD Techniques for Propulsion Applications 7 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by Ministry of Defence and Rolls-Royce Ltd.
(AGARD-CP-510) Copyright Avail: CASI HC A02/MF A06
A numerical representation of three dimensional turbulent flow within cooling ducts located in turbine blades and heat transfer into such ducts is effected using the finite element method. The importance of a coupled solid/fluid numerical model, when investigating heat transfer, is demonstrated by comparing numerical results with experimentally determined values relating to smooth,

cylindrical rotating passages. Having verified the numerical model, the technique is then used to evaluate heat transfer into a multi-ribbed rotating cylindrical duct. The enhancement of heat transfer, due to Coriolis induced secondary motion and the incorporation of ribs, is predicted and compared with experimental measurements. Author

N92-27475# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

PRESENTATION OF A COMPUTATIONAL CODE FOR 3-D COMPRESSIBLE FLOW IN COMPLEX CHANNELS AND CAVITIES [PRESENTATION D'UN CODE DE CALCUL D'ECOULEMENTS COMPRESSIBLES 3-D DANS DES CANAUX ET DES CAVITES DE FORME COMPLEXE]

D. DUTOYA, M. ERRERA, P. J. MICHARD, and A. RISTORI *In* AGARD, CFD Techniques for Propulsion Applications 21 p (SEE N92-27450 18-34) Feb. 1992 In FRENCH; ENGLISH summary Previously announced in IAA as A91-45650

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A computation code named MATHILDA was developed at ONERA to study mass and energy transfer through internal cooling systems composed of complex shaped channels and cavities in which the flow is controlled by the interaction between inertial forces and irreversible phenomena. This code integrates the 3D time dependent Navier-Stokes equations, along with some additional transfer equations. The fluid is compressible, and flow may vary from low subsonic to supersonic. The turbulence model can be either a two-equation model or an algebraic model. Author

N92-27476# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.

VALIDATION OF NON-ORTHOGONAL THREE-DIMENSIONAL LAMINAR FLOW PREDICTIONS

P. J. COELHO and J. C. F. PEREIRA *In* AGARD, CFD Techniques for Propulsion Applications 12 p (SEE N92-27450 18-34) Feb. 1992

(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06

Most of the flow geometries for aeronautical engineering are complex and cannot be discretized using orthogonal coordinates. In addition, some of those flows can only be described in the fully developed form of the Navier-Stokes equations. In this paper the Navier-Stokes equations are solved for three-dimensional complex geometries using a non-orthogonal, non-staggered coordinate system. The strong conservation form of the governing equations for laminar flows is discretized using a finite volume method. A numerical grid generation method is employed in order to easily generate the meshes. The flow through a square diffuser, the flow through a transforming duct of elliptical cross-section, and the flow through a square cross-section S-shaped duct were analyzed. The predictions reveal good agreement with the available data demonstrating the accuracy and generality of the present method. The present solution algorithm can easily be extended to calculate subsonic compressible flows. Author

N92-27477# Concordia Univ., Montreal (Quebec).

FINITE ELEMENT SOLUTION OF VISCOUS COMPRESSIBLE FLOWS IN GAS TURBINE DUCTS AND DIFFUSERS

W. G. HABASHI (Concordia Univ., Loyola Campus, Montreal (Quebec).), M. F. PEETERS (Concordia Univ., Loyola Campus, Montreal (Quebec).), M. P. ROBICHAUD (Concordia Univ., Loyola Campus, Montreal (Quebec).), V.-N. NGUYEN (Concordia Univ., Loyola Campus, Montreal (Quebec).), and M. V. BHAT (Pratt and Whitney Aircraft of Canada Ltd., Longueuil, Quebec) *In* AGARD, CFD Techniques for Propulsion Applications 11 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by Pratt and Whitney Aircraft of Canada Ltd.; Natural Sciences and Engineering Research Council of Canada; and Fonds pour la Formation de Chercheurs et l'Aide a la Recherche

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Aerodynamic losses incurred in gas turbine ducting are often substantial, contributing in a significant way to the overall compression or power loss. A finite element Navier-Stokes compressible turbulent code, NS3D, was under development between Pratt & Whitney Canada and Concordia University to help in the understanding of the flow field in such ducts and diffusers, in order to control the loss mechanisms. The code is based on a Newton-Galerkin finite element method, with equal order interpolation for velocities and pressure. The system of linear equations, at each Newton iteration, is solved for the primary variables (u,v,w,p) simultaneously, with either iterative methods designed to run on engineering workstations or with direct methods on supercomputers. Turbulence is modeled through the well-known (k, epsilon) model, with wall functions. The code was applied to the compressible turbulent analysis of intercompressor ducts and diffusers, and compares reasonably well to experiments. In addition, the code is being used to obtain improvement of duct performance through numerical redesign. Author

N92-27478# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Space Group.

AEROTHERMODYNAMICS OF NOZZLE FLOWS FOR ADVANCED HYPERSONIC PROPULSION SYSTEMS

C. WEILAND, G. HARTMANN, and S. MENNE *In* AGARD, CFD Techniques for Propulsion Applications 11 p (SEE N92-27450 18-34) Feb. 1992

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One of the major tasks for the development of novel airbreathing space transportation systems, operating from usual airports by horizontal take off and landing, is the integration of an advanced propulsion system in the cell of that spacecraft. The air intake and in particular the free expansion nozzle affect not only the efficiency of the engine but also the forces and moments, and with that, the control of the complete spacecraft. Therefore, it is necessary to know in detail the flow fields through such nozzles and its interaction with the external airflow. Another project deals with conventional rocket motor nozzles whereby injection of turbine exhaust gases in the expansion part of the nozzle the wall of the nozzle is cooled (filmcooling concept) and the thrust is slightly increased. Theoretical investigation of these and other nozzles is the objective of this paper. Euler and boundary layer methods will be applied to predict the flow fields of the nozzles where special emphasis is laid on the consideration of real gas effects. The theory of the Euler method will be described in detail while for the second order boundary layer method the governing equations are presented and the range of its applicability is shortly discussed. Finally results for a variety of nozzles will be given. Author

N92-27479# Technische Univ., Aachen (Germany). Inst. for Jet Propulsion and Turbomachinery.

APPLICATION OF FINITE ELEMENT METHOD TO HYPERSONIC NOZZLE FLOW COMPUTATIONS

W. KOSCHEL, W. RICK, and S. BIKKER *In* AGARD, CFD Techniques for Propulsion Applications 14 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by DFG

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An explicit Taylor-Galerkin Finite Element Method (FEM) algorithm, used for the solution of Euler/Navier-Stokes equations, is applied for the computation of steady-state frozen equilibrium flow in single expansion ramp nozzles (SERN) and in plug nozzles for hypersonic propulsion systems. External flow conditions are taken into account. For the determination of nozzle performance a detailed 2D/3D-flow analysis in regions with complex geometries was performed using unstructured computational grids with adaptive mesh refinement. Some results for the investigated nozzle configurations at different flight conditions are presented and discussed. Additionally, thrust vectoring by modification of the lower nozzle flap shape was studied. Author

N92-27480# Manchester Coll. of Science and Technology (England). Dept. of Mechanical Engineering.

COMPUTATIONAL MODELLING OF TURBULENT FLOW IN S-BENDS

N. I. ABOU-HAIDAR, H. IACOVIDES, and B. E. LAUNDER *In* AGARD, CFD Techniques for Propulsion Applications 16 p (SEE N92-27450 18-34) Feb. 1992 Sponsored in part by Rolls-Royce Ltd.

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The paper considers the computation of turbulent flow through circular sectioned S-bends, a flow generically similar to those arising in various types of jet-engine intake ducting. A fully elliptic, finite-volume discretization of the Reynolds equations is adopted. For the main part of the flow the standard algebraic second-moment (ASM) closure is adopted while over the thin, viscosity-affected

sublayer, adjacent to the wall, three types of model were explored: namely, one- and two-equation eddy viscosity models and a two-equation ASM closure. Although the main features of the flow development are well captured even with the simplest near-wall treatment, the pressure drop through the second half of the S-bend is seriously underestimated. The successive refinement of the model across the sublayer is found to bring the computed behavior into very close accord with the detailed experimental data. The findings indicate the desirability of using a high-level turbulence model not just in the main part of the flow but across the low-Reynolds-number sublayer also. Author

N92-27481# Aristotle Univ. of Thessaloniki (Greece). Lab. of Fluid Mechanics and Turbomachinery.
THREE DIMENSIONAL FLOW IN SHARP BENDS
K. FOTEA, P. PRINOS, and A. GOULAS *In* AGARD, CFD Techniques for Propulsion Applications 12 p (SEE N92-27450 18-34) Feb. 1992
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The three dimensional flow in sharp bends is computed by solving the fully elliptical three dimensional Navier-Stokes equations in conjunction with a k-epsilon model of turbulence. Computed isovelocity patterns before and after the sharp bend and recirculation lengths are compared with experimental measurements taken with Laser Doppler Anemometry. In general good agreement is obtained although the refinements in the turbulence modelling can improve the predictions. The computational results show that the recirculating region depends strongly on the inlet velocity profile. Finally, an increase in the aspect ratio of the duct indicates an increase of the region of the recirculation. Author

N92-27482# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).
THE 3-D NAVIER-STOKES FLOW AND TEMPERATURE FIELD COMPUTATION FOR A FORCED MIXER NOZZLE
K. KATHEDER *In* AGARD, CFD Techniques for Propulsion Applications 12 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06

To increase the temperature mixing efficiency in the common nozzle of an existing turbofan engine, a forced mixer is to be developed. Its design is based on empirically derived knowledge and requires some verification testing. To minimize the scope of testing, a numerical investigation has been performed, computing the complete flow path through the mixer up to the thrust nozzle. The computational domain is formed by a body fitted H-type grid. The simulated air flow is compressible adiabatic including variable specific heat and viscosity and the standard k-epsilon model is used. Resulting velocity and temperature fields are presented together with the temperature mixing efficiency. Use of the velocity field to shape the scallops at the mixer trailing edge is demonstrated. Comparison with test results indicates that computational fluid dynamics (CFD) is a useful engineering tool to check and improve a new design before testing. Author

N92-27483# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. of Propulsion Technology.
FLOW COMPUTATION IN COMBUSTION CHAMBERS USING ZONAL NONSTAGGERED GRIDS
M. RACHNER *In* AGARD, CFD Techniques for Propulsion Applications 18 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06

A Rhie-type nonstaggered grid three dimensional Navier-Stokes Code working on overlaid subdomains by a zonal technique is applied on two model combustion chambers. In the case of the swirling turbulent combustor flow investigated, a locally unrealistic flow behavior at domain boundaries was found on the coarse grid. This is caused by strong overshoots of the momentum interpolated cell mass fluxes, not reported up to now in the literature. The influence of the pressure gradient discretization at boundaries on these overshoots is shown. At inter grid boundaries the discretization of the pressure gradient can give rise to wiggles in the numerical solution as observed in the case of the reacting turbulent crossflow-H2-jet in a rectangular channel. Moreover the influence of fully, partially and lacking local flux conservativity in coupling the numerical fluxes across inter grid boundaries of the subdomain is studied. The fully conservative coupling scheme turned out be a nonrobust method. Author

N92-27485# Karlsruhe Univ. (Germany). Lehrstuhl und Inst. fuer Thermische Stroemungsmaschinen.
APPLICATION OF MONTE CARLO SIMULATION FOR THREE-DIMENSIONAL FLOWS
M. SCHEURLEN, B. NOLL, and S. WITTIG *In* AGARD, CFD Techniques for Propulsion Applications 10 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A02/MF A06

A Monte Carlo technique is outlined for the simulation of the transport of a joint scalar probability density function (PDF). The discretization of the partial differential equations is based on a finite volume approximation. The problem of frozen solutions is addressed if the number of stochastic elements is limited. Non-adiabatic boundary conditions are discussed if the energy equation is solved by a Monte Carlo simulation. The Monte Carlo simulation is compared with deterministic calculations and with an experiment in a three dimensional non-isothermal non-reacting jet mixing flow. The results of the simulation agree very well with the experiment and the deterministic calculations. However, the computer time and storage requirements for a three dimensional simulation of the transport of a single scalar PDF increases dramatically in comparison to deterministic calculations. The results also indicate the need for a simulation procedure that is free of numerical diffusion. Author

N92-27487# Politecnico di Torino, Torino (Italy). Dipartimento di Ingegneria Aeronautica e Spaziale.
NONEQUILIBRIUM 3D FLOWS OF AIR THROUGH INLETS
ROBERTO MARSILIO and MAURIZIO PANDOLFI *In* AGARD, CFD Techniques for Propulsion Applications 10 p (SEE N92-27450 18-34) Feb. 1992
(AGARD-CP-510) Copyright Avail: CASI HC A02/MF A06

The hypersonic nonequilibrium flow of air through inlets of propulsion devices is investigated. The fluid dynamics is described by the Euler equations and a chemical model accounts for finite rate equations. The numerical procedure is based upon a space marching technique, under the hypothesis of fully developed supersonic flow. The conservative form of the Euler and finite rate chemical equations are integrated, following a finite volume discretization and a flux difference splitting procedure. The numerical scheme is of the second order accuracy, with a proper total variation diminishing (TVD) technique to avoid spurious oscillations at flow discontinuities. Numerical results are presented and discussed. Author

N92-27488# Rome Univ. (Italy). Dipartimento di Meccanica e Aeronautica.
EVALUATION OF THE EFFECTS OF FINITE RATE CHEMISTRY ON NOZZLE PERFORMANCE
M. ONOFRI *In* AGARD, CFD Techniques for Propulsion Applications 11 p (SEE N92-27450 18-34) Feb. 1992
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Predictions of nozzle performance may be strongly affected by the choice of the flow model: large discrepancies with actual behaviors could occur if the two dimensional gasdynamic effects and the variations of chemical composition are not suitably accounted for, especially when the nonequilibrium region is wide enough and two dimensional gasdynamic phenomena interact significantly with chemical kinetics. In order to assess the accuracy of different simulations, a comparison among inviscid numerical solutions is performed for different classes of axisymmetric nozzles. The roles of the two dimensional effects on the global propulsive parameters is analyzed by comparing one and two dimensional solutions, while their influence on chemical kinetics is evaluated by considering frozen and nonequilibrium flow models. The numerical solution of the nonequilibrium nozzle flow model is performed by an implicit integration technique based on an operator splitting between gasdynamics and chemistry. While gasdynamics equations are integrated by the fast solver, the energy and mass fraction conservation equations are integrated in steady form along streamlines with a variable step procedure. This approach yields very efficient and accurate solutions even when the chemical variables display steep gradients. Author

N92-27489# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).
NUMERICAL ANALYSIS OF CONVERGING-DIVERGING NOZZLE FLOWS IN CHEMICAL NON-EQUILIBRIUM
R. WALTHER *In* AGARD, CFD Techniques for Propulsion Applications 8 p (SEE N92-27450 18-34) Feb. 1992
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The converging-diverging nozzle geometries, which are presently proposed for hypersonic propulsion systems, are characterized by large expansion area ratios, and by a geometrically variable nozzle throat to control the engine mass flow. Within the expanding nozzle flow, chemical recombination reactions of the combustor exhaust gas products will occur; the limited chemical reaction rates generally leading to a relaxation of the chemical species composition. In addition, changes in mixture composition and heat release due to chemical reactions influence the flow field. Based on Moretti's lambda-scheme a numerical model was developed which couples the gasdynamic phenomena with the chemistry effects that occur within the flow field. The chemical reaction rates are described by a kinetic model involving a satisfactory reaction mechanism. The developed scheme was applied to the expanding nozzle flow of a stoichiometric H2-air exhaust gas. For comparison, four different physical models have been considered to describe the chemical phenomena: chemically frozen flow; flow in chemical equilibrium; chemical equilibrium upstream of nozzle and nonequilibrium downstream of the nozzle; and flow in chemical nonequilibrium. The results are discussed in terms of flow properties, gas mixture composition, and nozzle exit momentum. It is concluded that a physically inadequate model of the chemical phenomena will lead to unacceptable discrepancies in net engine thrust predictions. Author

N92-27490# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THREE DIMENSIONAL CALCULATIONS OF REACTIVE FLOWS WITHIN AIRCRAFT COMBUSTION CHAMBERS INCLUDING SOME COMBUSTION MODELS [CALCULS TRIDIMENSIONNELS D'ECOULEMENTS REACTIFS DANS LES CHAMBRES DE COMBUSTION AERONAUTIQUES EFFECTUES A L'AIDE DE DEUX MODELES DE COMBUSTION]
FABIENNE PIT, HELENE TICHTINSKY, PASCALE GILBANK, and FRANCIS DUPOIRIEUX *In* AGARD, CFD Techniques for Propulsion Applications 15 p (SEE N92-27450 18-34) Feb. 1992 In FRENCH; ENGLISH summary Previously announced in IAA as A92-16089
(AGARD-CP-510) Copyright Avail: CASI HC A03/MF A06

Some three dimensional calculations have been performed in order to predict the reactive flow within aircraft combustion chambers. Two kinds of combustion models have been tested: on one hand a model which makes the assumption of fast chemistry but can however take roughly into account some aspects of the chemical kinetics through an ignition delay and, on the other hand, the Lagrangian-Eulerian PEUL model which can deal directly with some Arrehenius laws by means of the interaction by exchange with the mean (IEM) submodel and hence does not include some assumptions of fast reaction. Author

N92-27671# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON UNSTRUCTURED GRID METHODS FOR ADVECTION DOMINATED FLOWS
May 1992 362 p Special course held in Rhode-Saint-Genese, Belgium, 2-6 Mar. 1992 and at Moffett Field, CA, 28 Sep. - 2 Oct. 1992; sponsored in cooperation with VKI
(AGARD-R-787; ISBN-92-835-0671-5; AD-A256061) Copyright Avail: CASI HC A16/MF A03

Lecture notes for the AGARD Fluid Dynamics Panel (FDP) Special Course on 'Unstructured Grid Methods for Advection Dominated Flow' have been assembled in this report. The objective of this course was to provide state of the art information, as well as recent developments in unstructured grid methods, suitable for the computation of high Reynolds number compressible and incompressible flows, and other related subjects. A wide range of applications is presented, which includes incompressible free surface problems, transonic aerodynamics, and hypersonic reentry flows. For individual titles, see N92-27672 through N92-27680.

N92-27672# Chalmers Univ. of Technology, Goeteborg (Sweden). Dept. of Mathematics.
FINITE ELEMENT METHODS FOR FLOW PROBLEMS
CLAES JOHNSON *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 47 p (SEE N92-27671 18-34) May 1992
(AGARD-R-787) Copyright Avail: CASI HC A03/MF A03

The purpose of this note is to give an overview of the Streamline Diffusion Method (SDM), also referred to as Galerkin/Least Squares or Streamwise Upwind Petrov-Galerkin (SUPG), as a general finite element method for hyperbolic type differential equations modelling convection-diffusion, compressible/incompressible fluid flow or wave propagation. The SDM developed gives the first general solution to the fundamental problem of constructing finite element methods for hyperbolic problems with the desired combination of good stability and high accuracy. The SDM is a modified Galerkin method based on piecewise polynomial approximation with two modifications: a 'streamwise diffusion' modification of the test functions giving a weighted least squares control of the residual of the finite element solution; and the introduction of an artificial viscosity. Author

N92-27673# Stanford Univ., CA. Div. of Applied Mechanics.
FINITE ELEMENT METHODS FOR FLUIDS
THOMAS J. R. HUGHES *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 22 p (SEE N92-27671 18-34) May 1992
(AGARD-R-787) Copyright Avail: CASI HC A03/MF A03

The following topics are covered within this paper: stabilized methods; space-time formulation; symmetric linear advective-diffusion systems; incompressible Euler and Navier-Stokes equations, Stokes problem; compressible Euler and Navier-Stokes equations, entropy variables; nonlinear operators and shock capturing; solution algorithms; and examples. H.A.

N92-27674# Minnesota Univ., Minneapolis, MN. Supercomputer Inst.
FINITE ELEMENT COMPUTATION OF UNSTEADY INCOMPRESSIBLE FLOWS INVOLVING MOVING BOUNDARIES AND INTERFACES AND ITERATIVE SOLUTION STRATEGIES
TAYFUN E. TEZDUYAR *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 45 p (SEE N92-27671 18-34) May 1992
(AGARD-R-787) Copyright Avail: CASI HC A03/MF A03

In these lecture notes we review some of the recent progress on stabilized finite element formulation used in computation of incompressible flows. The stabilization techniques emphasized in these lecture notes are the Galerkin/least-squares, streamline-upwind/Petrov-Galerkin, and pressure-stabilizing/Petrov-Galerkin formulations. Most of the examples considered are unsteady flow problems, with emphasis on moving boundaries and interfaces, such as free surface flows, liquid drops, flow past an oscillating cylinder, and flow past an oscillating airfoil. Also reviewed are the iteration strategies employed to solve the implicit equation systems resulting from the finite element discretization of these flow problems, including space-time formulations. The lecture notes also describe a new mixed clustered-element-by-element (CEBE/CC) preconditioning method for finite element computations. Author

N92-27675# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). CFD Group.
MULTIDIMENSIONAL UPWIND METHODS FOR UNSTRUCTURED GRIDS
H. DECONINCK (CFC Products, Inc., Ann Arbor, MI.), R. STRUIJS (CFC Products, Inc., Ann Arbor, MI.), G. BOURGOIS (CFC Products, Inc., Ann Arbor, MI.), H. PAILLERE (CFC Products, Inc., Ann Arbor, MI.), and P. L. ROE (Michigan Univ., Ann Arbor.) *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 17 p (SEE N92-27671 18-34) May 1992
(Contract(s)/Grant(s): AERO-0003-C)
(AGARD-R-787) Copyright Avail: CASI HC A03/MF A03

In this contribution we describe a class of upwind schemes for hyperbolic conservation laws on unstructured grids consisting of triangles or tetrahedrons. Unlike standard upwind schemes which are based on a one dimensional physical model (the Riemann problem), the methods discussed here use a multidimensional

physical model for the upwinding. They do not fit in a standard finite volume approach with piecewise continuous representation of the unknowns. In this respect they are much closer to finite element methods based on linear elements, with which they share a continuous piecewise linear representation over the triangles or tetrahedrons. On the other hand they share with standard upwind methods the properties of asymmetric upwinded stencils and control of monotonicity over discontinuities, and they can be considered as truly multidimensional generalizations of the successful TVD upwind methods developed during the eighties.
Author

N92-27676*# University Coll. of Swansea (Wales). Dept. of Civil Engineering.
UNSTRUCTURED GRID METHODS FOR COMPRESSIBLE FLOWS
K. MORGAN (Swansea Tribology Centre (England).), J. PERAIRE (Swansea Tribology Centre (England).), and J. PEIRO (Imperial Coll. of Science and Technology, London, England) *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 39 p (SEE N92-27671 18-34) May 1992 Sponsored in part by Dassault-Breguet Aviation and Rolls-Royce Ltd.
(Contract(s)/Grant(s): NCCW-8; NAGW-478; NAGW-1809)
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The implementation of the finite element method on unstructured triangular grids is described and the development of centered finite element schemes for the solution of the compressible Euler equation on general triangular and tetrahedral grids is discussed. Explicit and implicit Lax-Wendroff type methods and a method based upon the use of explicit multistep timestepping are considered. In the latter case, the convergence behavior of the method is accelerated by the incorporation of a fully unstructured multigrid procedure. The advancing front method for generating unstructured grids of triangles and tetrahedra is described and the application of adaptive mesh techniques to both steady and transient flow analysis is illustrated. Author

N92-27677*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ASPECTS OF UNSTRUCTURED GRIDS AND FINITE-VOLUME SOLVERS FOR THE EULER AND NAVIER-STOKES EQUATIONS
TIMOTHY J. BARTH *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 61 p (SEE N92-27671 18-34) May 1992
(AGARD-R-787) Copyright Avail: CASI HC A04/MF A03

One of the major achievements in engineering science has been the development of computer algorithms for solving nonlinear differential equations such as the Navier-Stokes equations. In the past, limited computer resources have motivated the development of efficient numerical schemes in computational fluid dynamics (CFD) utilizing structured meshes. The use of structured meshes greatly simplifies the implementation of CFD algorithms on conventional computers. Unstructured grids on the other hand offer an alternative to modeling complex geometries. Unstructured meshes have irregular connectivity and usually contain combinations of triangles, quadrilaterals, tetrahedra, and hexahedra. The generation and use of unstructured grids poses new challenges in CFD. The purpose of this note is to present recent developments in the unstructured grid generation and flow solution technology. H.A.

N92-27678# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). CGD Group.
HIGHER ORDER UPWIND FINITE VOLUME SCHEMES WITH ENO-PROPERTIES FOR GENERAL UNSTRUCTURED MESHES
P. VANKEIRSBILCK and H. DECONINCK *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 54 p (SEE N92-27671 18-34) May 1992 Sponsored in part by Avions Marcel Dassault and Belgian National Fund for Scientific Research
(AGARD-R-787) Copyright Avail: CASI HC A04/MF A03

This contribution presents high resolution upwind finite volume schemes based on a polynomial reconstruction of the unknowns on unstructured polygonal cells. The schemes are essentially non-oscillatory (ENO) through the use of an adaptive stencil selection. A complete analysis and comparison given in this text shows that the order of the space accuracy of the schemes is at least equal to the degree of the reconstruction polynomial. Numerical results are shown for a nonlinear hyperbolic conservation equation, confirming the ENO shock capturing and higher order accuracy on highly irregular grids. More realistic Euler calculations will demonstrate the ability of the concepts that are outlined theoretically. Author

N92-27679# George Washington Univ., Washington, DC.
FINITE ELEMENT METHODS IN CFD: GRID GENERATION, ADAPTIVITY, AND PARALLELIZATION
RAINALD LOEHNER *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 58 p (SEE N92-27671 18-34) May 1992
(AGARD-R-787) Copyright Avail: CASI HC A04/MF A03

Numerical methods for the solution of field problems using unstructured grids have reached a high degree of maturity. Although computational fluid dynamics (CFD) have been dominated by structured grids, with the increase in computational ability, unstructured grids have started to have an impact on complex geometrical problems in CFD. The following paper describes grid generation, adaptive refinement schemes, visualization and parallelization issues. It also includes a short chapter on CFD among related disciplines that will help the newcomer with flow simulation codes. H.A.

N92-27680# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). CFD Group.
A FRONTAL APPROACH FOR NODE GENERATION IN DELAUNAY TRIANGULATIONS
J.-D. MUELLER (Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).), P. L. ROE (Michigan Univ., Ann Arbor.), and H. DECONINCK *In* AGARD, Special Course on Unstructured Grid Methods for Advection Dominated Flows 7 p (SEE N92-27671 18-34) May 1992
(AGARD-R-787) Copyright Avail: CASI HC A02/MF A03

A new algorithm for the generation of the interior nodes for Delaunay triangulation is given. The method uses a background grid to interpolate local mesh size parameters that are taken from the triangulation of the given boundary nodes. Geometric criteria are used to find a set of nodes in a frontal manner. This set is subsequently introduced into the existing mesh, thus providing an updated Delaunay triangulation. The procedure is completed when no more improvement of the grid by inserting new nodes can be achieved. Author

N93-13199# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
AERODYNAMIC ENGINE/AIRFRAME INTEGRATION FOR HIGH PERFORMANCE AIRCRAFT AND MISSILES [L'INTEGRATION AERODYNAMIQUE DES MOTEURS ET DES CELLULES DANS LES AVIONS ET LES MISSILES A HAUTES PERFORMANCES]
Sep. 1992 449 p In ENGLISH and FRENCH Symposium held in Fort Worth, TX, 7-10 Oct. 1991
(AGARD-CP-498; ISBN-92-835-0672-3; AD-A257974) Copyright Avail: CASI HC A19/MF A04

The objective of the symposium was to review the state-of-the-art in aerodynamic engine/airframe integration techniques and to report on the progress which has been achieved during engineering project work in recent years. Because the treatment of this subject requires an interdisciplinary approach, both experimentalists and theoreticians were invited to contribute to the meeting. Six sessions were organized to cover the essential subdisciplines requiring aerodynamic engine/airframe integration during the concept-assessment and design phases for new aerospace vehicles. For individual titles, see N93-13200 through N93-13231.

N93-13200# Aircraft Research Association Ltd., Bedford (England).
TEST TECHNIQUES FOR ENGINE/AIRFRAME INTEGRATION
A. E. HARRIS *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 17 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

The paper traces a path through modern experimental techniques in use for the study of installation performance in the

context of military and civil engine/airframe integration studies. For military and civil transport designs it is shown that separate treatment of air intake and exhaust regions is generally undertaken in contemporary methods. An early entry into the aerodynamics of the complete engine/airframe is emphasized in order to avoid costly integration difficulties. Using examples largely drawn from direct experience gained during the period 1960 to 1990 the author presents a set of 'most preferred methods' for use in high speed configuration development model tests. It is noted that current trends in civil and military designs require increased attention to be paid to off-axis thrust/drag/lift variations in the engine/airframe integration process. Methods of flow visualization are briefly reviewed and the emerging laser methods are also identified. The paper closes with a conceptual configuration for a year 2000 totally integrated engine/airframe to meet 21st century civil transport mass transit requirements. Author

N93-13201# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

TESTS OF MODELS EQUIPPED WITH TPS IN LOW SPEED ONERA F1 PRESSURIZED WIND TUNNEL [ESSAIS DE MAQUETTES MOTORISEES EQUIPEES DE SIMULATEURS DE REACTEURS DANS LA SOUFFLERIE BASSE VITESSE PRESSURISEE F1, DE L'ONERA]

J. LEYNAERT *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 5 p (SEE N93-13199 03-34) Sep. 1992 In FRENCH Previously announced in IAA as A92-26371

(AGARD-CP-498) Copyright Avail: CASI HC A01/MF A04

The particular conditions of tests of models equipped with a turbofan powered simulator (TPS) at high Reynolds numbers in a pressurized wind tunnel are presented. The high-pressure air supply system of the wind tunnel, the equipment of the balance with the high-pressure traversing flow and its calibration, and the thrust calibration method of the TPS and its verification in the wind tunnel are described. Author

N93-13202# Societe Nationale d'Etudes et de Construction de Moteurs Aeronautiques, Moissy-Cramayel (France). Centre de Villaroche.

NUMERIC SIMULATION OF THE AERODYNAMIC FLOWS AROUND NACELLES [SIMULATION NUMERIQUE DE L'ECOULEMENT AERODYNAMIQUE AUTOUR DES NACELLES]

J. L. LECORDIX, J. G. FRATELLO, and J. M. GIPPET *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 14 p (SEE N93-13199 03-34) Sep. 1992 In FRENCH

(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

With the aim of reducing the number and the cost of its tests, SNECMA obtained a three-dimensional Euler code. This code solves the Euler compressible equations put into conservative form, and at convergence is able to predict the aerodynamic flows around complex multidomain geometries. The numerical algorithm is of the finite volume type and is second order in time with a 2-step predictor-corrector approach. In addition, it uses a local time step and an artificial viscosity of the TURKEL-JAMESON type. This method was validated by calculations on isolated nacelles and the numerical results obtained reflected in a satisfactory manner those resulting from the tests. This code has been industralized and today allows the analysis of the aerodynamic lines of nacelles. Transl. by FLS

N93-13203# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

DETAILED ANALYSIS OF WING-NACELLE INTERACTION FOR COMMERCIAL TRANSPORT AIRCRAFT [ANALYSE DETAILLEE DE L'INTERACTION VOILURE-NACELLE D'UN AVION DE TRANSPORT CIVIL]

J. L. GODARD, O.-P. JACQUOTTE, and D. GISQUET (Aerospatiale, Toulouse, France) *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 11 p (SEE N93-13199 03-34) Sep. 1992 In FRENCH Previously announced in IAA as A92-16122

(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

An experimental setup has been developed to study the wing-nacelle interaction of commercial transports during transonic operation. This stand allows the measurement of the overall loads, pressure distribution on the model, and velocities in the field by laser velocimetry. The analysis gives a better understanding of the wing-nacelle interaction and provides the best comparative elements for modeling calculations. IAA

N93-13204# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Entwurfsaerodynamik.

INVESTIGATION OF INTERFERENCE PHENOMENA OF MODERN WING-MOUNTED HIGH-BYPASS-RATIO ENGINES BY THE SOLUTION OF THE EULER-EQUATIONS

C.-C. ROSSOW and A. RONZHELMER *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 11 p (SEE N93-13199 03-34) Sep. 1992

(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

With the development of Ultra-High Bypass (UHB) engines the aerodynamic interference between airframe and engine becomes increasingly important. In this study the solution of the Euler equations is used to simulate the flow field around the DLR-ALVAST wing-body combination with different wing-mounted engines. For a CFM-56 engine, which is taken here to represent a conventional engine, the contributions of single components like engine, pylon, and jet to the aerodynamic interference were investigated. The comparison with the flow field around the wing-body combination without engine showed that the presence of the engine alone lead to a forward movement of the shock on the complete upper surface of the wing. The pylon mainly influenced the lower surface and caused an additional loss of lift which is of the same order of magnitude as the loss due to the engine. The simulation of an inviscid jet showed no significant influence for the conventional engine. A further comparison of the interference effects of the CFM-56 engine and a UHB engine was made. The geometry of the UHB engine corresponds to the DLR-CRUF simulator for Ultra-High Bypass engines. Due to the closer installation to the wing and the larger dimensions, the UHB engine caused a local flow acceleration on the lower surface of the wing. This lead to a significant loss of lift at the engine position, compared to the conventional engine. Simulation with and without jet revealed that the jet was mainly responsible for this behavior. In case of the UHB engine the jet passed very closely under the wing and the displacement effect of the jet caused a strong flow acceleration. Author

N93-13206# Vigyan Research Associates, Inc., Hampton, VA.

EULER ANALYSIS OF TURBOFAN/SUPERFAN INTEGRATION FOR A TRANSPORT AIRCRAFT

D. A. NAIK, H. C. CHEN (Boeing Co., Seattle, WA.), T. Y. SU (Boeing Co., Seattle, WA.), and T. J. KAO (Boeing Co., Seattle, WA.) *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 12 p (SEE N93-13199 03-34) Sep. 1992

(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

A three-dimensional general multi-block Euler solver (GMBE) has been developed to analyze the propulsion integration effects of turbofan/superfan installations. Either flow-through or powered nacelles can be modelled. The code is demonstrated on a generic NASA low wing transport model with an advanced turbofan flow-through nacelle. The results compare favorably with experimental data obtained in the NASA Langley 16-Foot (4.88 m) Transonic Tunnel. The computed pressure distributions are used to identify, in terms of pressure coefficient peaks (maximum negative values) and gradients, undesirable flow regions in the vicinity of the pylon and nacelle. The results suggest that a change in toe angle and pylon trailing edge closure geometry will improve the propulsion integration. Author

N93-13209# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany). Inst. fuer Strahlantriebe.

OVERVIEW ON TEST CASES FOR COMPUTATION OF INTERNAL FLOWS IN TURBOMACHINES

LEONHARD FOTTNER *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 5 p (SEE N93-13199 03-34) Sep. 1992

(AGARD-CP-498) Copyright Avail: CASI HC A01/MF A04

Aero engine component design and development makes increasing use of computer codes for flow field calculations, such as two- or three-dimensional flow fields and flow fields with strong viscous effects. The accuracy of these calculation methods

depends on the mathematical models and numerical schemes used to describe the physical reality. The proof of validity and the refinement of such methods depend on verification against relevant test cases, primarily experimental test cases. The AGARD Propulsion and Energetics Panel established Working Group 18 to specify relevant reference test cases to serve as validation bases for new methods, but also as check for existing production codes. The present paper gives an overview on the results of the Working Group and briefly describes the different test cases. These test cases refer to analytical and experimental test cases for steady flow in linear compressor and turbine cascades, single blade rows, single and multistage axial compressors and turbines and ducts. In addition, suggestions for future tests designed to reduce the limitations are discussed. Author

N93-13210# Vrije Univ., Brussels (Belgium). Dept. of Fluid Mechanics.

THE PEP SYMPOSIUM ON CFD TECHNIQUES FOR PROPULSION APPLICATIONS

CH. HIRSCH *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 18 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

This is part of the PEP contribution to the 69th FDP meeting on Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles. It presents an overview of the main outcomes of the last PEP meeting dealing with CFD techniques for propulsion applications. The emphasis was given to computational work on realistic 3D configurations, covering the four following topics: full 3D validations; full 3D numerical techniques; unsteady flows and multidimensional reacting flows. In addition, an invited paper from FDP on the state of the art of computational techniques for 3D Navier-Stokes equations and a technical evaluation of the meeting were presented. The most widely stressed conclusion was the urgent need for a large scale effort on validation of numerical accuracy and of physical models. Author

N93-13211# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).

THE INFLUENCE OF INTAKE SWIRL DISTORTION ON THE STEADY-STATE PERFORMANCE OF A LOW BYPASS, TWIN-SPOOL ENGINE

W. MEYER, W. PAZUR (Universitaet der Bundeswehr Muenchen, Neubiberg, Germany), and LEONHARD FOTTNER (Universitaet der Bundeswehr Muenchen, Neubiberg, Germany) *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 20 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

Intakes of supersonic aircraft can produce intake swirl configurations in front of the engine which are important for intake/engine compatibility assessment throughout the flight envelope. The main objective of this investigation was to get more information about the influence of intake twin swirl on the steady-state engine behavior. The twin swirl was simulated using a movable delta wing positioned between the bellmouth intake and the engine. By changing the angle of attack of the delta wing, the intensity of the intake swirl could be varied. Increasing the intensity of the twin swirl resulted in a deterioration of engine performance. The analysis of the test results showed that these effects on engine performance were mainly due to a modified characteristic of the low pressure compressor (LPC). Therefore, it was very important to investigate the changed LPC performance to be able to understand the effects of an intake swirl distortion on the engine performance. Hence, an experimental method was set up to measure the performance map of the installed LPC by defined changing of the engine operating line. An analysis of experimentally determined compressor maps for varying intensities showed that the performance parameters of the LPC decrease. However, there is essentially no variation of the engine's working line due to an intake twin-swirl distortion. Semi-empirical calculations which took account of this influence of the generated swirl on the performance of the LPC confirmed the loss of engine performance observed during the engine tests. Author

N93-13216# Aeronautica Macchi S.p.A., Varese (Italy). Aerodynamics Div.

WATER TUNNEL STUDIES OF INLET/AIRFRAME INTERFERENCE PHENOMENA

R. MAGGIO *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 12 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

Some experimental studies of inlet/airframe interference, conducted at the Aermacchi's Water Tunnel facility about aircraft configurations under consideration for an Advanced Trainer Project, are presented. The chin inlet and the bifurcated inlet configurations have been considered, and the following phenomena have been investigated: inlet/forebody interference at low incidence; inlet/ground interference at take off conditions; and inlet/airframe interference. All the above mentioned studies are based on flow visualizations in water tunnel, merged with theoretical studies, semiempirical, and handbook methods. Author

N93-13217# Kingston Polytechnic, Kingston-Upon-Thames (England). School of Mechanics, Aeronautics, and Product Engineering.

EXPERIMENTAL STUDIES OF THE FLOWFIELDS AND THEIR EFFECTS DUE TO A PAIR OF LIFT JETS DISCHARGING IN THE GROUND EFFECT REGION

L. J. HOPE and E. C. P. RANSOM *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 19 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

A small rig has been designed and made to study fountain flows formed by subsonic jets impinging onto a ground plane. A series of tests was carried out to investigate three dimensional flow patterns and pressure distributions in the fountain flows. A program of tests was then devised to establish fountain flow pressures and normal forces on rectangular blocking trays of various designs. Most tests were carried out at ambient temperature but some tests were carried out with pre-heated compressed air. The effect of the distance between the jets and the trays from the ground plane was examined and recorded. Moving ground board tests were also performed. Author

N93-13220*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

AGARD WG13 AERODYNAMICS OF HIGH SPEED AIR INTAKES: ASSESSMENT OF CFD RESULTS

N. C. BISSINGER (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany), T. J. BENSON, and R. G. BRADLEY, JR. (General Dynamics Corp., Fort Worth, TX.) *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 24 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

A brief review of the work accomplished by the numerical subgroup of AGARD Working Group 13 on the aerodynamics of high speed air intakes is presented. This work comprised the selection of test cases for which experimental data were available. The test cases were chosen to range in complexity from normal-shock/boundary-layer interaction to full forebody-inlet combinations. Computations for these test cases were solicited from a large number of organizations and individual researchers within the NATO countries. The computation methods reached from Euler solvers (with and without boundary layer corrections) to full Reynolds averaged Navier-Stokes codes. The group compared these results with the test data available for each test case. A short overview of the CFD methods employed, a description of the test cases selected, and some of the comparisons between CFD solutions and test data are presented. The conclusions and recommendations drawn from this assessment are given. Author

N93-13225# General Dynamics Corp., Fort Worth, TX.

CALIBRATION OF 2D UNSTRUCTURED GRID METHODS ON PROPULSIVE FLOWFIELDS

STEVE L. KARMAN, JR. and GREGORY S. SPRAGLE *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 12 p (SEE N93-13199 03-34) Sep. 1992
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A computational fluid dynamics (CFD) method is presented for the analysis of complex two-dimensional (2D) geometries using unstructured grid techniques. The grid generation procedure uses

a split tree technique for subdividing the domain and generating internal mesh points. A Delaunay triangulation method is employed to triangulate the points, then iteratively refines the mesh based on cell aspect ratios and area variation to improve the quality of the initial mesh. The full Navier-Stokes equations are solved using an upwind flux difference splitting scheme for the inviscid flux and a central differencing scheme for the viscous flux. A two equation turbulence model is included for analyzing turbulent flows. A Jacobi iteration procedure is used to solve the linear set of implicit equations at each time step. Two 2D propulsive flowfields are analyzed and compared with experimental data. The grids are adapted to the flowfield by refinement based on the flowfield gradients. Improved resolution of the pertinent flowfield features were a result of the grid adaption employed. Author

N93-13226# General Dynamics Corp., Fort Worth, TX.
CFD CALIBRATION FOR THREE-DIMENSIONAL NOZZLE/AFTERBODY CONFIGURATIONS
CHRISTOPHER L. REED and ARNOLD MUYSHONDT *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 11 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

The current trend in fighter aircraft design is toward highly integrated propulsive exhaust systems. In order to achieve this level of integration, extensive testing and analysis is required. Modern computational fluid dynamics (CFD) techniques have become popular in performing a part of the required analyses. Because of the complexity of most nozzle/afterbody type flow fields, Navier-Stokes codes are generally the preferred CFD methods. To gain confidence in these solvers ability to provide useful design information, a number of calibration analyses must be conducted. Extensive test data are available for these comparisons. This paper describes three such analyses which were used to calibrate two Navier-Stokes codes. The first case deals with the internal flow through a vectored nozzle. The second case looks at the development of an exhaust plume issuing from a rectangular nozzle. The third case considers the flow over an afterbody with a high-aspect-ratio rectangular nozzle. In all cases, both qualitative and quantitative comparisons are made between the test data and the CFD data. Good comparisons are obtained and additional confidence is gained in these CFD codes ability to provide useful engineering data. Author

N93-13227# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany).
INVESTIGATION OF THE FLOWFIELD AROUND AN ISOLATED BYPASS ENGINE WITH FAN AND CORE JET
R. RUDNIK, A. RONZHEIMER, C.-C. ROSSOW, and H. HOHEISEL *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 8 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A02/MF A04

A finite-volume scheme for the discretization of the three-dimensional Euler equations is extended for the purpose of calculating the flowfield around an isolated bypass engine with fan- and core-jet. Flow calculations for a typical high bypass engine are performed for take-off and cruise conditions under consideration of realistic operational jet parameters. Several variations of the jet pressure and temperature ratio show that the jet flowfield is dominated by the pressure ratio as far as inviscid flow is concerned. A comparison of the numerical results to experimental investigations, which are carried out with a turbine powered simulator for low speeds, exhibits good agreement. The influence of numerical parameters on the solution in the region of the jet flow is analyzed by varying the coefficients of the artificial dissipation. Author

N93-13231# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
AIR INLET WITH VARIABLE INTAKE SECTION: APPLICATION TO AIR BREATHING LAUNCH VEHICLES [PRISES D'AIR A SECTION DE CAPTATION VARIABLE APPLICATION AUX LANCEURS AEROBIES]
F. FALEMPIN and PH. DUVEAU *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 8 p (SEE N93-13199 03-34) Sep. 1992 In FRENCH
(AGARD-CP-498) Copyright Avail: CASI HC A02/MF A04

The feasibility of air breathing propulsion for future space launch vehicles largely depends on the possibility of designing air intakes that will give the best trade-off between internal performance and which will provide suitable air supply to the engine, weight reduction, and aerodynamic drag. The trade-off can be markedly improved by using air intake designs with variable absorption sections. The design concepts are defined and their application to space launch vehicles is analyzed with respect to internal performance, mass, and aerodynamic drag. Transl. by L.B.

N93-29935# Wright Lab., Wright-Patterson AFB, OH. Aero Propulsion and Power Directorate.
HEAT TRANSFER IN HIGH TURBULENCE FLOWS: A 2-D PLANAR WALL JET
R. B. RIVIR, W. T. TROHA, W. A. ECKERLE (Cummins Engine Co., Inc., Columbus, IN.), and W. J. SCHMOLL (Dayton Univ. Research Inst., OH.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 12 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

The accurate prediction of turbine heat transfer remains beyond our current capabilities. To investigate this condition, nonconventional turbulence generation techniques have been employed to explore the impact of high turbulence or unsteadiness on heat transfer. The heat transfer from a 2D planar wall jet is compared with an axisymmetric wall jet with twice the turbulence scale and more turbulent kinetic energy - with an increased heat transfer shown by the planar configuration. The resulting comparisons of wall jet augmented heat transfer to engine turbine blade heat transfer is quite favorable. Derived from text

N93-29936# Purdue Univ., West Lafayette, IN. School of Mechanical Engineering.
HEAT TRANSFER WITH MODERATE FREE STREAM TURBULENCE
S. N. B. MURTHY *In* AGARD, Heat Transfer and Cooling in Gas Turbines 33 p (SEE N93-29926 11-07) Feb. 1993
(Contract(s)/Grant(s): F49620-87-K-0008)
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

Turbulence in turbine flows of gas turbine engines is generally inhomogeneous and is also characterized by wide ranges of intensity and scale. The interaction between Free Stream Turbulence (FST) and boundary layer turbulence (BLT) is complicated in all but the case of low values of both intensity and scale. In a recent investigation, an attempt was made to establish the effect of homogeneous FST on wall friction (when there is no heat transfer) in the relatively simple case of a flat plate, zero pressure gradient boundary layer. In the current paper, the method was extended for the prediction of heat transfer in the same flow field. In any problem involving heat and momentum transport, it is common to introduce some type of similarity between the two transport processes. The current method is based on the application of a similarity rule governing the spectra of turbulence intensity and temperature variance. The principal outcome is a method of establishing heat transfer in a given flow field for which experimental data are available under cold flow conditions and have been verified with the model prediction scheme.
Author (revised)

N93-29937# University Coll. of Swansea (Wales). Dept. of Mechanical Engineering.
THE EFFECT OF ORTHOGONAL-MODE ROTATION ON FORCED CONVECTION IN A CIRCULAR-SECTIONED TUBE FITTED WITH FULL CIRCUMFERENTIAL TRANSVERSE RIBS
W. D. MORRIS and R. SALEMI *In* AGARD, Heat Transfer and Cooling in Gas Turbines 11 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by Science Research Council and Rolls-Royce Ltd.
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04
This paper presents the results of an experimental program aimed at investigating the effect of Coriolis forces and centripetal buoyancy on forced convection in an internally finned circular tube which rotates about an axis orthogonal to the tube's central axis. This geometric arrangement typifies the internal coolant channels of gas turbine rotor blades. It is demonstrated that, as with smooth-walled tubes, Coriolis-driven secondary flows give rise to relatively better heat transfer on the trailing edge of the tube compared with that on the leading edge. Leading edge heat transfer is shown to be significantly impaired in relation to that which occurs under non-rotating conditions. Centripetal buoyancy is shown to improve local heat transfer on the leading and trailing edges for a given value of the through flow Reynolds number and the Rossby number. Although duct rotation tends to improve heat transfer on the trailing edge in comparison with normal stationary duct forced convection, serious overprediction of heat transfer results from ignoring rotational effects on the leading edge. This is an important observation in the context of the design of turbine rotor blade cooling systems. Author (revised)

N93-29940# Oxford Univ., Oxford (England). Dept. of Engineering Science.
FUNDAMENTAL STUDIES OF IMPINGEMENT COOLING THERMAL BOUNDARY CONDITIONS
M. G. LUCAS, P. T. IRELAND, Z. WANG, T. V. JONES, and W. J. PEARCE (Rolls-Royce Ltd., Bristol, England.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 10 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by Ministry of Defence; Science Research Council; and Rolls-Royce Ltd.
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04
Measurements were made of the local heat transfer at the surface of a flat plate underneath a confined impinging jet. Thermochromic liquid crystals were used to measure the surface temperature of a uniformly heated plate cooled by an impinging jet. The temperature of the wall through which the jet passes was controlled, and experiments were performed to measure the two heat transfer coefficients which arise from this three temperature problem. The effect of Reynolds number and plate to jet spacing on heat transfer was investigated. The heat transfer results are discussed in terms of the interpreted flow field. Author (revised)

N93-29941# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).
PREDICTION OF JET IMPINGEMENT COOLING SCHEME CHARACTERISTICS (AIRFOIL LEADING EDGE APPLICATION)
A. RIAHI, H. J. SAABAS, and W. ABDEL MESSEH *In* AGARD, Heat Transfer and Cooling in Gas Turbines 14 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04
A control volume, finite difference method based on the work of Rhie in conjunction with a high Reynolds k-epsilon model and a two layer turbulence model was used to predict the heat transfer coefficients underneath an impinging circular jet in the absence of cross flow. The numerical results are compared to experimental measurements for two different impingement height to jet diameter ratios: $H/D = 2$, and $H/D = 10$. The comparisons indicate that, although both the k-epsilon and the two layer turbulence models are adequate in the prediction of the flow field, the two layer model resulted in heat transfer predictions that were closer to experimental observations. It was also observed that the predicted heat transfer coefficients for the case of $H/D = 2$ were sensitive to the assumed jet exit turbulence levels, whereas they were not for $H/D = 10$. This information is useful to the designer of cooled turbine components. Author (revised)

N93-29944# Nottingham Univ. (England). Dept. of Mechanical Engineering.
THE SWOLLEN POLYMER TECHNIQUE AND ITS USE FOR HEAT TRANSFER INVESTIGATIONS ON FILM COOLED SURFACES
N. HAY, D. LAMPARD, and N. MACLEOD (Edinburgh Univ., Scotland.) *In* AGARD, Heat Transfer and Cooling in Gas Turbines 21 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04
The Swollen Polymer Technique is a mass transfer analogy method for obtaining heat transfer data. It is similar in principle to the naphthalene method, but it has an advantage in that it can be combined with interferometric measuring methods giving a panoramic view of the distribution of the transfer coefficient over the working surface. Additionally, the mass transfer process is reversible, and the working surface can be used repeatedly. Changes in thickness of a polymer coating on the working surface, initially swollen with an ester, are measured, using holographic interferometry to yield a fringe pattern depicting loci of equal transfer coefficient over the surface. The paper describes the basis of the method, the equipment required to implement it, the precautions necessary for its successful use, its advantages, its limitations, and its future potential. The technique yields data useful in the design process. Examples of its application to film cooled surfaces are given, including the effects of geometry, density ratio, and acceleration of the mainstream flow on the heat transfer coefficient. Extension of the technique for the simultaneous measurement of effectiveness and heat transfer coefficient is described, and its further extension for use with curved surfaces is outlined. A recent development to the technique itself by the use of a thermoplastic plate for recording the holograms opens up the possibility of further advancement using electronic image processing. Author (revised)

N93-29948# Institut de Mecanique des Fluides de Marseille (France).
STUDY OF FLOW STRUCTURE IN ROTATING CAVITIES: NUMERICAL PREDICTIONS OF LAMINAR AND TURBULENT, STEADY, AND UNSTEADY FLOWS
P. MAUBERT, R. SCHIESTEL, L. ELENA, A. RANDRIA-MAMPIANINA, A. M. CHAOUCHE, E. CRESPODELARCO, and P. BONTOUX *In* AGARD, Heat Transfer and Cooling in Gas Turbines 23 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by CCVR; CNRS; IMT; Conseil Regional PACA; Defence Research Establishment Toronto; International Exchange Program; and Ministere des Affaires Etrangeres
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04
The flow regimes in rotating cavities (modelling corotating disks or rotor-stator systems), with or without through flow, are studied by numerical approach using different techniques: spectral and finite volume methods. Comparisons between these techniques have been carried out for a typical test case. The solutions have been also compared satisfactorily to asymptotical approximations and to experimental results. The computations with spectral methods have been carried out until the onset of unsteady instabilities and transition to turbulence. The turbulent regimes have been treated with the finite volume method based on modelling derived from a k-epsilon or algebraic model of second order. Author (revised)

N93-29952# Technische Univ., Darmstadt (Germany). Inst. fuer Technische Thermodynamik.
FLUID FLOW AND HEAT TRANSFER IN THE ENTRANCE REGION OF AN ANNULUS BETWEEN INDEPENDENTLY ROTATING TUBES WITH A TURBULENT AXIAL FLOW
H. PFITZER, T. ROTHE, and H. BEER *In* AGARD, Heat Transfer and Cooling in Gas Turbines 11 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04
Experimental and numerical investigations of turbulent flow and heat transfer have been performed in the entrance region of a concentric annulus between independently rotating tubes. The horizontally mounted test section has an electrically heated outer wall and an adiabatic inner wall. The mean heat transfer rate in the hydrodynamic and thermal entrance region as well as the local Nusselt number at the axial position z/db(sub h) approx. = 60, which is the end of the rotating annular channel, were determined experimentally. Hotwire and thermocouple probes

allowed for measurement of velocity and temperature distributions at the end of the annulus. Numerical predictions, applying a k-epsilon eddy viscosity model with a modification by the flux Richardson number, are compared with the experimental results. The comparison shows that general effects of the rotation can be predicted quite well with the aid of a simple turbulence model. Due to stabilizing or destabilizing effects of centrifugal forces in the fluid and due to the additional shear stress, the rotation of the inner and the outer tube influences remarkably fluid flow and heat transfer in the annulus. Author (revised)

N93-29953# Technische Univ., Darmstadt (Germany).
THE EFFECT OF MAIN STREAM FLOW ANGLE ON FLAME TUBE FILM COOLING
H. KLINGER and D. K. HENNECKE *In* AGARD, Heat Transfer and Cooling in Gas Turbines 12 p (SEE N93-29926 11-07) Feb. 1993 Sponsored in part by BMFT
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

Generally film cooling configurations are positioned such that they are oriented perpendicular to the main stream flow direction. However in many cases, in particular combustor applications, different flow angles may occur. Then, due to the interaction between the main stream and the cooling film, a complex three-dimensional flow field with a vortex is formed. An experimental study was done to study the basic effects. The cooling configuration was a vertical slot which could be turned by up to about 60 degrees from the position perpendicular to the main stream. Velocity distributions were measured and the adiabatic film cooling effectiveness was determined using the liquid crystal technique. The results show that, along lines parallel to the slot, the film cooling effectiveness varies strongly, even with small slot turning angles. This would lead to hot and cold spots in a combustor application. A simple semi-empirical correlation for the average cooling effectiveness is derived using the main stream velocity component perpendicular to the slot. Author

N93-29954# Leeds Univ. (England). Dept. of Fuel and Energy.
IMPINGEMENT/EFFUSION COOLING
G. E. ANDREWS, A. M. ALDABAGH, A. A. ASERE, F. BAZDIDI-TEHRANI, M. C. MKPADI, and A. NAZARI *In* AGARD, Heat Transfer and Cooling in Gas Turbines 10 p (SEE N93-29926 11-07) Feb. 1993
(Contract(s)/Grant(s): SRC-GR/D/53029)
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

Impingement/effusion cooling offers one of the most effective ways of cooling gas turbine combustor walls and turbine blades. The design principles are reviewed and cooling effectiveness data presented for a range of typical geometries with holes at 90 degrees to the surface. The main variable studied was the number of impingement/effusion holes. Comparison was made with the effusion cooling effectiveness. Optimum configurations were demonstrated with a 0.7 overall cooling effectiveness at a mass flow per unit surface area of 0.2 kg/sm(exp 2)bar. This was equivalent to 10 percent of the combustor air flow for a typical gas turbine combustor. Data is also presented for the overall wall heat transfer coefficient. The mechanism of the enhanced heat transfer within the impingement/effusion double skin wall was investigated using a CFD code. This predicted the complex aerodynamics in the impingement gap and also gave good agreement with the measured overall heat transfer data. Author (revised)

N93-29955# Middle East Technical Univ., Ankara (Turkey). Dept. of Chemical Engineering.
EVALUATION OF MULTI-DIMENSIONAL FLUX MODELS FOR RADIATIVE TRANSFER IN CYLINDRICAL COMBUSTION CHAMBERS
NEVIN SELCUK *In* AGARD, Heat Transfer and Cooling in Gas Turbines 6 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04

Four flux-type models for radiative heat transfer in cylindrical configurations were applied to the prediction of radiative flux density and source term of a cylindrical enclosure problem based on data reported previously on a pilot-scale experimental combustor with steep temperature gradients. The models, which are Schuster-Hamaker type four-flux model derived by Lockwood and Spalding, two Schuster-Schwarzschild type four-flux models derived by Siddall and Selcuk and Richter and Quack and spherical harmonics approximation, were evaluated from the viewpoint of predictive accuracy by comparing their predictions with exact solutions produced previously. The comparisons showed that spherical harmonics approximation produces more accurate results than the other models with respect to the radiative energy source term and that the four-flux models of Lockwood and Spalding and Siddall and Selcuk for isotropic radiation field are more accurate with respect to the prediction of radiative flux density to the side wall. Author

N93-29956# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
CALCULATIONS OF REACTIVE TURBULENT FLOWS IN AERONAUTICAL CHAMBERS [CALCULS D'ECOULEMENTS TURBULENTS REACTIFS DANS LES FOYERS AERONAUTIQUES]
P. CAILLAU and F. DUPOIRIEUX *In* AGARD, Heat Transfer and Cooling in Gas Turbines 13 p (SEE N93-29926 11-07) Feb. 1993 In FRENCH
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

The progress which was recently achieved in the modeling of turbulent combustion for applications to propulsion are described. The averaged equations of reactive turbulent flows are given, then the Probabilist EUlerian Langrangian model (PEUL) intended for the calculation of the average source terms of categories and of enthalpy are presented. The possibility of taking into account by this model the reactional mechanisms to several categories is applied to the prediction of the pollutants and in particular to the calculation of thermal NO. In order to obtain the best possible prediction of the chemical composition and the temperature, three total mechanisms of oxidation of methane are successively coupled with the PEUL model and their results compared. Two applications are then studied. The first application is a premixed flame stabilized by a hot gas flow. The computation results are compared with the experimental results obtained with ONERA and present a suitable agreement, in particular with regard to the profiles of thermal NO. The second concerns a portion of an annular aeronautical chamber. The comparison of the average production rates obtained with a model of turbulent combustion with rapid chemistry and with the PEUL model highlights, in this case, the importance of not making the hypothesis of rapid chemistry. Author (revised)

N93-29959# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
ON THE DEVELOPMENT OF A FILM COOLING LAYER
F. LOPEZ PENA and T. ARTS *In* AGARD, Heat Transfer and Cooling in Gas Turbines 12 p (SEE N93-29926 11-07) Feb. 1993 Sponsored by Commission of the European Communities
(AGARD-CP-527) Copyright Avail: CASI HC A03/MF A04

Different aerodynamic aspects of the flow field generated when a single jet or a row of jets are ejected into a mainstream are experimentally investigated. The similarity parameters are taken such as to match those of the three-dimensional film cooling. The objective is to deepen the understanding of the complex phenomena associated with these flows, and to provide a comprehensible and detailed data base for validation of numerical codes. To be able to obtain high resolution measurements, the study is made on large scale models. The scale enlargement obliges to use moderate velocities, so that the Reynolds number can be kept within realistic limits and the similarity preserved. The use of low air speeds prevents the analysis of compressibility effects. This restriction is not as severe as one can think because, according to the related bibliography, these effects start to be noticeable at Mach numbers higher than 0.8, while the designers avoid to inject the coolant in the vicinity of shock waves to avoid boundary layer separation. The study is made on three different models installed in a low speed wind tunnel. A first model consists of a flat plate with a single inclined circular hole. The isolated jet/mainstream interaction is investigated by means of this first test plate. The other two models present the same configuration as the first but having now a row of holes with different pitch to diameter ratios in each case. These models are useful to understand the interaction between jets and to analyze the formation and development of the coolant layer. Author (revised)

N94-10439*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A CFD VALIDATION ROADMAP FOR HYPERSONIC FLOWS
JOSEPH G. MARVIN *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 16 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

A roadmap for computational fluid dynamics (CFD) code validation is developed. The elements of the roadmap are consistent with air-breathing vehicle design requirements and related to the important flow path components: forebody, inlet, combustor, and nozzle. Building block and benchmark validation experiments are identified along with their test conditions and measurements. Based on an evaluation criteria, recommendations for an initial CFD validation data base are given and gaps identified where future experiments would provide the needed validation data. Author (revised)

N94-10441# Texas Univ., Austin, TX. Center for Aeromechanics Research.
PROBLEMS IN THE VALIDATION OF CFD CODES THROUGH COMPARISON WITH EXPERIMENT
DAVID S. DOLLING *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 15 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

Accurate predictions of the effects of shock wave turbulent boundary layer interactions are of particular importance in the design of hypersonic vehicles. Such flows can generate intense heat transfer rates and pressure levels, complex large-scale unsteady separated flows, and large-amplitude fluctuating loads. With increased reliance on computation, it is critical that the predictions are accurate. Thus, it is imperative that such codes be validated and calibrated and deficiencies be identified and rectified. Comparison of the predictions of computational fluid dynamics (CFD) codes with experimental data is the key element of the validation process. However, drawing meaningful conclusions about the strengths and weaknesses of solution methodologies or of turbulence models from these comparisons is not a trivial task. As recently stated by Jameson, 'Simply comparing experimental data with numerical results provides no way to distinguish the source of the discrepancies, whether they are due to faulty numerical approximation or programming, or to deviations between the math model and true physics.' The conclusions drawn may be quite misleading if it is not clearly understood what the computations represent and what the experimental data represent. This paper discusses why it is important to know how experimental mean flowfield and surface data being used for comparison with CFD are generated. If the flowfields exhibit local or global large-scale unsteadiness, then such mean measurements, which form the bulk of the existing data base, may mask the underlying flow physics and be inappropriate for comparison with computation. Author (revised)

N94-11493# Universite Catholique de Louvain (Belgium). Mecanique Appliquee.
STABILITY OF VISCOELASTIC FLOW: PHYSICAL AND NUMERICAL CONSIDERATIONS
M. J. CROCHET and C. BODART *In* AGARD, Stability in Aerospace Systems 16 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

The topics are presented in viewgraph form and include the following: viscoelastic flow; numerical difficulties -- the high Weissenberg number problem; efficient algorithms for smooth problems; efficient algorithms for singular problems; experimental evidence of instability; numerical procedure for verifying stability; and numerical results. CASI

N94-11498# Centre d'Etudes et de Recherches, Toulouse (France). Aerothermodynamics Dept.
BOUNDARY LAYER TRANSITION: PREDICTION AND WIND TUNNEL SIMULATION
D. ARNAL *In* AGARD, Stability in Aerospace Systems 12 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

This paper gives a survey of theoretical and experimental results related to the problem of boundary layer transition; emphasis is given on applications of practical prediction methods. In the first part of the paper, it is shown that the linear stability theory can provide a good estimate of the transition location if the free stream disturbance level is low enough; the difficulties to properly simulate free flight conditions in ground facilities is underlined. The second part of the paper is devoted to the problem of boundary layer tripping in the presence of large external disturbances; in this case, the linear theory no longer applies and empirical criteria need to be developed. Derived from text

N94-15119# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
ADVANCED METHODS FOR CASCADE TESTING [METHODES AVANCEES POUR LES ESSAIS DES GRILLES D'AUBES]
CHARLES HIRSCH, ed. (Vrije Univ., Brussels, Belgium.) Aug. 1993 196 p
(AGARD-AG-328; ISBN-92-835-0717-7; AD-A270634) Copyright Avail: CASI HC A09/MF A03

Considerable advances have been achieved over the last decennia in the field of cascade testing, but they were generally not reported in sufficient detail. As an example, details of transonic/supersonic cascade testing procedures were scarcely documented in literature. Many other aspects evolved considerably, originally from the progress of experimental techniques as well as from the interaction with computer data. New methodologies based on advanced instrumentation gained sufficient validation. Consequently, the Propulsion and Energetics Panel decided to initiate an AGARDograph on this subject in 1988. Since then, several authors prepared chapters for the AGARDograph, coordinated by the editor. The following chapters are included: Modeling Turbomachinery Flow Conditions, Linear Cascades, Annular Cascades, Aspects of Hot Cascades, Transient Cascade Testing, Unsteady Flow in Cascades, and 3-D Laser Anemometry in Annular Cascades. Author (revised)

N94-15196# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON SHOCK-WAVE/BOUNDARY-LAYER INTERACTIONS IN SUPERSONIC AND HYPERSONIC FLOWS [INTERACTIONS ENTRE ONDES DE CHOC ET COUCHES LIMITES DANS LES ECOULEMENTS SUPERSONIQUES ET HYPERSONIQUES]
Aug. 1993 298 p Course held in Rhode-Saint-Genese, Belgium, 24-28 May 1993; sponsored by VKI Original contains color illustrations
(AGARD-R-792; ISBN-92-835-0718-5; AD-A271730) Copyright Avail: CASI HC A13/MF A03

Notes for the AGARD Fluid Dynamics Panel (FDP) Special Course on 'Shock-Wave/Boundary-Layer Interactions in Supersonic and Hypersonic Flows' are presented. The objective was to report on results from recent research programs providing a consolidated review of these activities and a sound basis for developing more reliable methodologies for future vehicle design. The course also provided a focused review of recent progress for swept interactions in both laminar and turbulent flows, including discussions: flowfield structure; scaling and similarity laws; effect of shock strength on flow feature; effect of shock generator geometry for a given shock strength; techniques for investigating swept interactions, particularly optical techniques; and contributions of numerical simulations to the understanding of swept interactions. The effects of turbulence and turbulence modeling on the flowfields are provided. For individual titles, see N94-15197 through N94-15203.

N94-15197*# Pennsylvania State Univ., University Park, PA. Gas Dynamics Lab.
SWEPT SHOCK/BOUNDARY-LAYER INTERACTIONS: SCALING LAWS, FLOWFIELD STRUCTURE, AND EXPERIMENTAL METHODS
GARY S. SETTLES *In* AGARD, Special Course on Shock-Wave/Boundary-Layer Interactions in Supersonic and Hypersonic Flows 40 p (SEE N94-15196 03-34) Aug. 1993 Sponsored by NASA. Ames Research Center and AFOSR
(AGARD-R-792) Copyright Avail: CASI HC A03/MF A03

A general review is given of several decades of research on the scaling laws and flowfield structures of swept shock wave/turbulent boundary layer interactions. Attention is further restricted to the experimental study and physical understanding of the steady-state aspects of these flows. The interaction produced

by a sharp, upright fin mounted on a flat plate is taken as an archetype. An overall framework of quasiconical symmetry describing such interactions is first developed. Boundary-layer separation, the interaction footprint, Mach number scaling, and Reynolds number scaling are then considered, followed by a discussion of the quasiconical similarity of interactions produced by geometrically-dissimilar shock generators. The detailed structure of these interaction flowfields is next reviewed, and is illustrated by both qualitative visualizations and quantitative flow images in the quasiconical framework. Finally, the experimental techniques used to investigate such flows are reviewed, with emphasis on modern non-intrusive optical flow diagnostics. Author

N94-15198# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). Aerospace Dept.

SWEPT SHOCK WAVE/LAMINAR BOUNDARY LAYER INTERACTIONS, EXPERIMENTAL, AND NUMERICAL RESULTS

G. DEGREZ *In* AGARD, Special Course on Shock-Wave/Boundary-Layer Interactions in Supersonic and Hypersonic Flows 19 p (SEE N94-15196 03-34) Aug. 1993
(Contract(s)/Grant(s): AERO-0027-C)
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Experimental and numerical investigations of swept shock wave/laminar boundary layer interactions are reviewed. Experimental investigations show that the flowfield is characterized by an extensive primary separation of the boundary layer upstream of the inviscid shock wave, which then rolls up into a very elongated vortex. This is often accompanied by secondary and sometimes higher order separations. Similar to turbulent interactions, the flowfield is essentially conical as far as the surface flow data are concerned (surface pressures, heat transfer, and skin friction patterns). Also, the free-interaction concept introduced for turbulent interactions is shown to apply to laminar interactions as well. Recent LDV flowfield data for a supersonic interaction are presented. They nicely confirm the vortical structure of the interaction deduced from the surface data as well as the important thickening of the viscous layer due to separation. They also show that the vertical dimension of the interaction does not obey a conical similarity rule but rather follows the classical boundary layer scaling. Numerical investigations confirm these experimental findings. None of these was however carried out with sufficient grid resolution so as to demonstrate grid convergence and code validity, in particular concerning the location of separation lines. Author (revised)

N94-15199# Rutgers - The State Univ., Piscataway, NJ. Dept. of Mechanical and Aerospace Engineering.

NUMERICAL SIMULATION OF 3-D SHOCK WAVE TURBULENT BOUNDARY LAYER INTERACTIONS

DOYLE D. KNIGHT *In* AGARD, Special Course on Shock-Wave/Boundary-Layer Interactions in Supersonic and Hypersonic Flows 32 p (SEE N94-15196 03-34) Aug. 1993
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The capability for numerical simulation of 3-D shock wave turbulent boundary layer interactions is assessed. Specific configurations examined include the sharp fin, blunt fin, cylinder/flare, swept compression corner and crossing shock. Future needs in improved computational methods, collaborative experimental/computational efforts and incorporation of knowledge of flowfield structure into more effective designs are discussed. Author (revised)

N94-15200*# Texas Univ., Austin, TX. Center for Aeromechanics Research.

UNSTEADY PHENOMENA IN SHOCK WAVE/BOUNDARY LAYER INTERACTION

D. S. DOLLING *In* AGARD, Special Course on Shock-Wave/Boundary-Layer Interactions in Supersonic and Hypersonic Flows 46 p (SEE N94-15196 03-34) Aug. 1993
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A brief review is given of the unsteadiness of shock wave/turbulent boundary layer interaction. The focus is on interactions generated by swept and unswept compression ramps, by flares, steps and incident shock waves, by cylinders and blunt fins, and by glancing shock waves. The effects of Mach number, Reynolds number, and separated flow scale are discussed as are the physical causes of the unsteadiness. The implications that the unsteadiness has for interpreting time-average surface and flowfield data, and for comparisons of such experimental data with computation, is also briefly discussed. Finally, some suggestions for future work are given. It is clear that there are large gaps in the data base and that many aspects of such phenomena are poorly understood. Much work remains to be done. Author

N94-15201# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Aerodynamics Dept.

CONTRIBUTION OF LASER DOPPLER VELOCIMETRY TO THE PHYSICAL DESCRIPTION OF SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTIONS WITH INCIDENCE ON TURBULENCE MODELLING

J. M. DELERY *In* AGARD, Special Course on Shock-Wave/Boundary-Layer Interactions in Supersonic and Hypersonic Flows 34 p (SEE N94-15196 03-34) Aug. 1993
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With the advent of Laser Doppler Velocimetry (LDV) in the 1970's, it became possible to investigate high speed complex flows containing shock waves, separated regions, and strong turbulent fluctuations. This powerful tool has allowed an unprecedented physical description of the flow fields resulting from shock wave/boundary layer interaction, both in two- and three-dimensional flows. It is remarkable that the development of LDV accompanied the progress in CFD, thus permitting an in depth validation of the theoretical models. The Lecture focusses on the use of LDV to investigate typical transonic and supersonic interactions occurring, firstly in nominally 2D configurations, then in a 3D channel flow. The data thus obtained are used to validate a detailed description of the flow field and to validate several equilibrium and non-equilibrium turbulence models. In 2D flows, the calculations were executed by using an economical boundary layer type approach, for the 3D case the models were implemented in a Navier-Stokes code. Author (revised)

N94-15202# Institut National des Sciences Appliquees, Routen (France). Lab. de Mecanique des Fluides Numerique.

TURBULENCE MODELLING FOR SHOCK WAVE/BOUNDARY LAYER INTERACTIONS SPECIFIC ISSUES AND EXAMPLES OF APPLICATIONS

D. VANDROMME *In* AGARD, Special Course on Shock-Wave/Boundary-Layer Interactions in Supersonic and Hypersonic Flows 68 p (SEE N94-15196 03-34) Aug. 1993
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Since the pioneering theory of Boussinesq and the first application indicated by Prandtl, turbulence modeling has been continuously improved in order to allow effective prediction of turbulent flows. Since these early contributions, various methodologies were worked out to account properly for 'complex' effects on turbulence. Among others, these 'complex' effects are caused by curvature, body forces (gravitation or magnetic fields), unsteadiness, and variable density. In fact, in real flows situations, it is often difficult to separate these effects, and the prediction of a flow configuration of industrial interest must always combine the simultaneous treatment of several effects. Depending on the application domain, some effects can be considered as dominant which allows neglect of others completely. As an example, geophysical flows in oceans are dominated by stratification and rotation, while compressibility or solid boundary effects can be neglected. In contrast, flows around an aircraft fuselage in real flight conditions are strongly influenced by compressibility and wall effects and not at all by gravitation or rotation. Because of the requirements imposed by a wide variety of industrial and aeronautical problems, one of the biggest challenges, during the last few years in the field of turbulence modeling was the correct accountability of the variable density effects. Variable density can have different origins, which can result for instance from: (1) the mixture of gases with different density; (2) a temperature gradient within an homogeneous fluid; (3) compressibility in high speed flows; or (4) reactive flows (for instance flames, chemical or gasdynamic laser flows). Unfortunately, until now, only a small fraction of the modeling effort has been devoted to these flows. Author

N94-15203# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Aerothermodynamics Section.
HYPERSONIC SHOCK WAVE BOUNDARY LAYER INTERACTIONS OVER SIMPLIFIED DEFLECTED CONTROL SURFACE CONFIGURATIONS
G. SIMEONIDES *In* AGARD, Special Course on Shock-Wave/Boundary-Layer Interactions in Supersonic and Hypersonic Flows 47 p (SEE N94-15196 03-34) Aug. 1993 Sponsored in part by Dassault Aviation Original contains color illustrations
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The problem of hypersonic shock wave boundary layer interactions over simplified geometric configurations that simulate the vicinity of deflected control surfaces on lifting reentry vehicles is addressed. The discussion evolves primarily around surface pressure and heat transfer data over flat plate/two-dimensional and swept compression ramp configurations, and the axisymmetric hyperboloid/flare configuration, emphasizing the prediction of peak heating in regions of interaction, the promotion of laminar-turbulent transition, and the performance and validation of CFD codes. Following a brief overview of the fundamental physical phenomena associated with shock wave boundary layer interactions, as these have been identified and summarized in the extensive literature available on the subject, the paper is split into three main parts. The first part concentrates on the analysis of global pressure and heat transfer distributions and their comparison with simple boundary layer theory, emphasizing peak heating at the downstream end of the interaction region. The second part addresses the formation of streamwise striations in reattaching flow regions, and the associated spanwise heat transfer variations which may exceed plus or minus 50 percent of the mean local heating level. Last but not least, the performance and limitations of state-of-the-art Navier-Stokes computations in computing hypersonic separated flows are illustrated by means of a series of computational fluid dynamics (CFD) code validation test cases assembled in recent years. Author (revised)

N94-28003# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
COMPUTATIONAL AND EXPERIMENTAL ASSESSMENT OF JETS IN CROSS FLOW [EVALUATION NUMERIQUE ET EXPERIMENTALE DES JETS DANS DES COURANTS TRANSVERSAUX]
Nov. 1993 479 p In ENGLISH and FRENCH Symposium held in Winchester, England, 19-22 Apr. 1993 Original contains color illustrations
(AGARD-CP-534; ISBN-92-835-0720-7) Copyright Avail: CASI HC A21/MF A04
The 37 papers prepared for the AGARD Fluid Dynamics Panel (FDP) Symposium on Computational and Experimental Assessment of Jets in Cross Flow are included. The primary objective of the Symposium was to provide a forum for assessing advances made in the technology and application of jets in cross flow which have occurred since the last meeting on this subject. Major topics covered included enhanced descriptions of the fundamental flow structure of jets in cross flow, experimental methods, thrust vectoring, jet impingement and exhaust gas reingestion, hypersonic crossflow, and numerics and turbulence modeling. For individual titles, see N94-28004 through N94-28040.

N94-28004*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FIFTY YEARS OF JET IN CROSS FLOW RESEARCH
RICHARD J. MARGASON *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 41 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A03/MF A04
The jet in cross flow (JICF) is a basic flowfield which is relevant to a wide variety of applications which are described to provide context for JICF investigations. Material consistent with the scope of topics presented at the 72nd AGARD Fluid Dynamics Panel Meeting and Symposium on Computational and Experimental Assessment of Jets in Cross Flow on 19-22 April 1993 in Winchester, U.K. is summarized. The JICF research was divided into three time periods: (1) early research - up to 1970, (2) research during the 1970's, and (3) research since 1980. The following areas of experimental activity are discussed; the definition of an effective correlation parameter; the jet flowfield including the jet trajectories, cross-section shape, and jet induced pressures; the effects of jet deflection angle, nozzle shape, pressure ratio, velocity decay, and temperature; and the effect of confined flowfield, ground effects, multiple jets, and adjacent surface geometry. In addition, computational methods are discussed including both potential flow based methods, some with empirical and semi-analytical extensions, and Navier-Stokes based computational fluid dynamics (CFD) investigations. Currently modern CFD methods have been able to compute many of the mean flow characteristics of the JICF. Existing CFD methods have not resolved the separated flow region in the near wake of the jet exit. There is also a need for high quality, extensive experimental data which will enable the verification of current and future CFD results and to define unsteady flow characteristics. Author (revised)

N94-28005# Southampton Univ. (England). Dept. of Aeronautics and Astronautics.
TRANSIENT FLOW FEATURES OF A SUPERSONIC JET IN A LOW SPEED CROSS FLOW
X. ZHANG (City Univ., London, England.), D. W. HURST, and G. M. LILLEY *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 16 p (SEE N94-28003 07-34) Nov. 1993
(Contract(s)/Grant(s): D/ERI/9/4/2040/4)
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The transient features of a supersonic jet exhausting into a low speed cross flow were studied experimentally. The experiments were conducted in the Southampton University's 3.5 m x 2.6 m low speed wind tunnel. Three supersonic jets at ambient temperatures were used, one being a convergent nozzle and the other two being convergent-divergent nozzles having respectively design Mach numbers, M_d = 1.4 and 1.7. Each jet issued in the normal direction to a flat plate mounted at zero incidence in the center of the wind tunnel. The jet pressure ratio varied between 1.2 and 5.0 and the cross flow velocity between 14m/s and 38m/s. Both over-expanded and under-expanded jets were used. The low speed cross flow was found to introduce complex multiple narrow band tones. Changes in the transient flow modes and the levels of the tones were observed from time resolved pressure measurements at various positions on the flat plate. Author (revised)

N94-28006# Commonwealth Scientific and Industrial Research Organization, Highett, Victoria (Australia). Div. of Building, Construction and Engineering.
UNSTEADY WAKE STRUCTURES IN TRANSVERSE JETS
R. M. KELSO, C. DELO (Princeton Univ., NJ.), and A. J. SMITS (Princeton Univ., NJ.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 8 p (SEE N94-28003 07-34) Nov. 1993 Sponsored in part by Fannie and John Hertz Foundation and NSF
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04
The unsteady vortex structures in the wake of a transverse jet were studied using a new laser scanning apparatus to obtain three-dimensional images of fluorescent dyes in a water channel flow. By scanning the laser at high repetition rates and by using a high-speed video camera to record the images, the three-dimensional, time-evolving concentration field in the wake can be obtained and later reconstructed. Using this system, the separation and roll-up of the flat plate boundary layer and the subsequent convection of that vorticity away from the wall can be visualized. The relationship between the separation and roll-up on the other side of the wake can also be studied. On the basis of the reconstructed concentration fields, an attempt is made to describe the mechanisms of wake vortex formation and explain the results of some previous authors. Author

N94-28007*# Florida Agricultural and Mechanical Univ., Tallahassee, FL. Dept. of Mechanical Engineering.

SEPARATED FLOW GENERATED BY A VECTORED JET IN A CROSSFLOW

A. KROTHAPALLI and C. SHIH *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 7 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by NASA. Ames Research Center Prepared in cooperation with Florida State Univ., Tallahassee

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Results of an experimental investigation to determine the characteristics of the separated flow region generated by a subsonic vectored rectangular jet in a subsonic crossflow is presented. Using surface visualization techniques, it was found that the upstream separated flow consist of horseshoe vortices that are formed periodically with a frequency corresponding to that of the vortex shedding behind the jet. The size of the recirculation region around the jet is found to decrease with increasing jet vector angle. The variation of the mean primary separation distance upstream of the jet, with velocity ratio revealed the existence of two different flow regimes. The change from one to the other depends on the velocity ratio and the jet vector angle. It is shown that the Strouhal number, based on the vortex shedding frequency and a combination of jet exit and freestream velocities, varies uniquely with velocity ratio. Author

N94-28008# Stanford Univ., CA. High Temperature Gasdynamics Lab.

SCALAR MIXING IN THE SUBSONIC JET IN CROSSFLOW

S. H. SMITH, A. LOZANO, M. G. MUNGAL, and R. K. HANSON *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 13 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by AFOSR

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Results are presented on the structure and mixing of subsonic jets in crossflow. These results are obtained by using planar laser-induced fluorescence of acetone vapor which is carried as a marker of the jet fluid. In addition to providing instantaneous realizations of the jet structure, the data is quantitative in providing instantaneous measures of the jet mixture fraction. Jet to crossflow velocity ratios ranging from 6 to 14, corresponding to momentum ratios of 36 to 196 were examined. It is found that the instantaneous structure is quite complex, dominated by large-scale motions, and bear little resemblance to ensemble-averaged field. Jet fluid is seen in the wake structure in the curved portion of the jet, even though the amounts are small. Mean and rms concentration fluctuations are presented for select cases. Author (revised)

N94-28009# Surrey Univ., Guildford (England). Fluid Mechanics Research Group.

THE INTERACTION REGION ASSOCIATED WITH TWIN JETS AND A NORMAL CROSSFLOW

N. TOY, E. SAVORY, S. MCCUSKER, and P. J. DISIMILE (Cincinnati Univ., OH.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 11 p (SEE N94-28003 07-34) Nov. 1993

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An experimental investigation of the interaction between twin jets and a normal crossflow using real-time, quantitative, video image analysis of smoke-seeded jets to yield information concerning overall jet growth rates, the widths of the interface regions, intermittencies, p.d.f.s, and spectra of the interface fluctuations is presented. The cases covered are side-by-side and in-line jets, with a nozzle spacing of 5 nozzle exit diameters and a jet velocity/crossflow velocity ratio of 8, together with the single jet cases. Additional data, in the form of velocity vector distributions from five-hole pressure probe measurements, were obtained for comparison with the intermittency profiles in planes across the jets for the case of side-by-side jets with a nozzle spacing of 5 diameters and a ratio of 6. Finally, a parametric study of the effect on the overall jet penetration of velocity ratio (from 4 to 10), nozzle spacing (from 1 to 5 diameters) and nozzle orientation to the crossflow (from in-line to side-by-side, but with normal injection angle) was carried out using a new digital image processing system. The velocity data for the side-by-side case shows that the deflected jets are dominated by one single vortex pair such that the inner vortex of each jet pair are not evident. The video analysis of the three main configurations, side-by-side, in-line and single jet, shows that in all cases the width of the mixing region at any downstream location is similar in magnitude to the jet half-width (as defined by the mean interface location). The interface widths are similar for the side-by-side and in-line jets but these are greater than the single jet for the intermittency distributions across the interface regions which will enable correlation between the different jet configurations. The parametric study shows that, for a given jet ratio, the in-line jets (0 deg angle) penetrate further than those set at other angles to the crossflow and that changes of angle between 30 deg and 60 deg have less effect upon the overall penetration. For the in-line case it is the second jet, issuing into the lower static pressure region downstream of the first jet, that penetrates furthest into the crossflow. Author

N94-28010# Loughborough Univ. of Technology (England). Dept. of Transport Technology.

EXPERIMENTAL DATA FOR CFD VALIDATION OF IMPINGING JETS IN CROSSFLOW WITH APPLICATION TO ASTOVL FLOW PROBLEMS

P. BEHROUZI and J. J. MCGUIRK *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 11 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by British Aerospace Public Ltd. Co.

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An experimental facility, used to gather validation data suitable for testing CFD model predictions of multijet ground impingement flows, is described. Water is used as the working medium and LDV measurements of twin impinging jets are reported, both with and without a cross-flowing stream. Emphasis is placed on the presentation of mean and rms velocity contours in the foundation formation region between the jets. The effect of jet splay angle has also been studied. For zero splay or 10 deg of splay-out, the fountain is observed to develop as an upwash flow spatially separated from the two jet flows (jet spacing at six jet diameters); for 10 deg splay-in, a noticeable fountain/jet interaction is observed. Splay-out reduces the strength of the fountain by around 50 percent whereas splay-in has an opposite, strengthening effect for the seven jet diameter impingement height studied here. The effect of a cross-flow (jet/cross-flow velocity ratio of 10) leads to a clear downwind shift of the fountain origin and inclination of the fountain rise. The results presented offer a sufficiently comprehensive mapping of the mean velocity and turbulence fields to form suitable test cases for the validation of CFD models for ground effect flows. Author (revised)

N94-28011# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).

EXPERIMENTAL INVESTIGATION OF THE INTERACTION OF A THRUST REVERSER JET WITH AN EXTERNAL SUBSONIC FLOW

J.-M. CHARBONNIER, K. DECKERS, and G. WENS *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) Nov. 1993

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An experimental modelization of a door-type thrust reverser is conducted in a subsonic wind tunnel. The geometry of the model is defined in order to simulate both the internal and external flow of a real thrust reverser. Different door configurations are studied for a selected value of the mass flux injection ratio of three. Visualizations illustrate qualitatively the jet interaction, and extensive mean velocity and pressure measurements are conducted in sections perpendicular to the upstream flow direction with a five hole probe. The total pressure losses and the drag force produced by the thrust reverser are deduced from the measurements. As a result, it shows that the smaller opening angle of the door (56 deg), with a becquet deflection of 15 deg gives the larger drag force. In addition to the classical pair of counter rotating vortices observed in jet in cross flow interactions, a second pair of counter rotating vortices below the main pair is found. The vorticity field is described with good agreement by a simple vortex model simulating the two pairs of vortices. Author (revised)

N94-28012# Nangia Associates, Bristol (England).
VECTORED JETS-INDUCED INTERFERENCE ON AIRCRAFT, PREDICTION AND VERIFICATION
R. K. NANGIA *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 14 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by Defence Research Agency
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The prediction of vectored jet-induced effects on V/STOL configurations during transition phase and maneuvers constitutes an important aspect in the understanding, design, control, and operation of such aircraft. In this paper, a semiempirical modelling of the jet is used within the framework of subsonic singularity methods. Comparisons with experimental data on a wing-body configuration have been presented. In general, acceptable agreement has been demonstrated. Overall, the emphasis has been on predicting jet interference effects on practical configurations with multijet effects and forward and aft nozzles. Configuration effects include tails which operate in a much stronger jet downwash than the wing. Optimization studies can be enabled prior to experimental programs. This process will allow the design cycle to commence with a good idea of the relative effectiveness of the various controls and the changes needed in the flight control system to cope with partially jet-borne phases of flight. Therefore there is a significant potential for encouraging cost and time savings. Areas for further work and improvements of the model have been proposed. It is believed that these aspects will have a constructive impact on current and future practical VSTOL and ASTOVL developments. Author (revised)

N94-28013# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft.
NUMERICAL INVESTIGATION OF THRUST VECTORING BY INJECTION OF SECONDARY AIR INTO NOZZLE FLOWS
T. BERENS *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 15 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by DGLR
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Injection of secondary air into nozzle flows is an efficient method to control the thrust vector angle of an aircraft. A numerical investigation of thrust vectoring has been carried out for hypersonic aircraft in the transonic flight regime. In this speed range, single duct asymmetrical single expansion ramp nozzles operate far off design due to large nozzle exit areas required for optimal thrust coefficients at hypersonic cruise Mach numbers, thus producing large thrust components in the downward direction. Injecting secondary air into the nozzle flow in the critical transonic flight Mach number regime can lead to favorable gross thrust vector angles and thus improved thrust efficiency in flight direction. For a hypersonic aircraft's rectangular convergent-divergent nozzle configuration with a single expansion ramp, two dimensional Euler calculations of the complete afterbody flow field were carried out in the transonic flight regime, investigating subsonic as well as supersonic injection of the aircraft's forebody boundary layer air into the nozzle flow. Subsonic flow of the injected air along the expansion ramp produces a favorable pressure distribution on the ramp and results in advantageous thrust vectors with small force components normal to the flight direction and in best thrust efficiency. The interaction between the external flow, the jet plume flow, and the secondary air flow, as well as the behavior of the thrust vector, due to pressure and temperature variations of the injected forebody boundary layer air, are discussed. Also investigated was the impact of the aircraft's angle of attack on the complete nozzle flow field. Author (revised)

N94-28014# Melbourne Univ., Parkville (Australia). Dept. of Mechanical and Manufacturing Engineering.
TOPOLOGICAL STRUCTURE OF A JET IN A CROSS FLOW
A. E. PERRY, R. M. KELSO, and T. T. LIM *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 8 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by Australian Research Council Original contains color illustrations
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Experimental studies of round jets in cross flow have been made using flying hot-wire and flow visualization techniques. The velocity ratio of the flow ranged from about two to six with the Reynolds number up to 6200. The flying hot wire enables time- and phase-averaged measurements to be made in regions of the flow which cannot be measured accurately using stationary wires. These quantitative results together with the complementary flow visualization studies have allowed the mean topological features of the jet in cross flow to be identified using critical point theory. An understanding of these flow features may provide insight into the large-scale mixing processes which occur in the shear layer of the jet. Author (revised)

N94-28015# Stanford Univ., CA. Environmental Fluid Mechanics Lab.
AN EXPERIMENTAL STUDY OF SIPHONAL JETS IN A TURBULENT BOUNDARY LAYER CROSSFLOW
C. A. ORIORDAN, S. G. MONISMITH, and J. R. KOSEFF *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 11 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by NSF and Charles Lee Powell Foundation
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Experiments were conducted in a laboratory flume to study the interaction of bivalve siphonal jets with the turbulent boundary layer which forms in the benthic region of shallow estuaries. Beds of siphonate bivalves (clams) 1.8 meters long were simulated to study the formation of a phytoplankton-depleted layer (concentration boundary layer) over bivalves. Refiltration of excurrent fluid through incurrent siphons, which represents a decrease in aggregate feeding efficiency, was measured for two test beds with S/d(sub o) = 6 and 16 and siphon pairs oriented perpendicular to the cross flow direction. Results are expressed as a function of the nondimensional distance downstream, x/d(sub o), the velocity ratio, VR=u(sub j)/U(sub infinity), and the nondimensional animal spacing, S/d(sub o). Laser induced fluorescence was used to obtain quantitative concentration profiles in order to describe the evolution of the flow and to identify parameters that describe the jet/boundary layer interaction. Author (revised)

N94-28016*# Wright Lab., Wright-Patterson AFB, OH.
EXPERIMENTS ON THE GROUND VORTEX FORMED BY AN IMPINGING JET IN CROSS FLOW
WILLIAM B. BLAKE and VEARL R. STEWART (KSA Technology, Columbus, OH.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 13 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by NASA. Langley Research Center and KSA Technology
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An inclined jet impinging on the ground creates a wall flow that spreads radially from the point of impingement. If a cross-flow is introduced, the upstream component of the wall flow will separate from the ground and create what has been termed the 'ground vortex.' The ground vortex has been shown to have a significant impact on aircraft aerodynamics and is one of the major contributors to hot gas ingestion. The paper discusses a recent study which included a generic wing-body configuration for assessing the impact of the ground vortex on configuration aerodynamics. Wind tunnel tests using fixed ground boards, moving ground belts, and moving model tests are discussed. The emphasis of the data is macroscopic, i.e. forward location of the vortex, effects of ground height, etc. Author (revised)

N94-28023*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A NUMERICAL INVESTIGATION OF A SUBSONIC JET IN A CROSSFLOW
STEPHEN H. CHIU (Space Systems/Loral, Palo Alto, CA.), KARLIN R. ROTH, RICHARD J. MARGASON, and JIN TSO (California Polytechnic State Univ., San Luis Obispo.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 14 p (SEE N94-28003 07-34) Nov. 1993 Original contains color illustrations
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The flowfield induced by a single, subsonic jet exhausting perpendicularly from a flat plate into a subsonic crossflow has been numerically investigated. The test case was chosen to match available experimental data where the jet Mach number was 0.78, and the freestream Mach number was 0.13. Time-averaged solutions were obtained using the thin-layer Navier-Stokes equations and two overlapping grids. The solutions were sensitive to the radial grid clustering near the edge of the jet and to the far-field boundary conditions. Experimental data comparisons were

required to determine the most appropriate jet grid and satisfactory boundary conditions. Globally, the solutions converged in about 6000 iterations. The computational results accurately showed the deflected jet and associated contrarotating vortices. The fine clustered grid in the region upstream of the jet exit allowed the horseshoe vortex in the boundary layer near the jet exit to be captured. Most importantly for aircraft applications, the computed plate pressure distributions compared favorably with the experimental data over most of the surface. However, in the wake region immediately downstream of the jet exit, where there is extensive flow separation, some discrepancies with experimental data were observed. Two turbulence models were used in this study: (1) the zero-equation, two layer Baldwin-Lomax turbulence model; and (2) one-equation Baldwin-Barth turbulence model. The turbulence models gave results which generally compared no better with experimental data than the laminar computation results.
Author (revised)

N94-28024# Manchester Coll. of Science and Technology (England). Dept. of Mechanical Engineering.
CALCULATION OF SINGLE AND MULTIPLE JETS IN CROSS-FLOW WITH AND WITHOUT IMPINGEMENT USING REYNOLDS-STRESS-TRANSPORT CLOSURE
N. Z. INCE and M. A. LESCHZINER *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 14 p (SEE N94-28003 07-34) Nov. 1993 Sponsored in part by British Aerospace Public Ltd. Co.
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A finite-volume algorithm, incorporating a non diffusive quadratic scheme for the approximation of convection and full second-moment (Reynolds-stress-transport) turbulence closure, is applied to a free jet in moderately strong cross-flow and three jet configurations combining impingement with weak cross-flow, one geometry involving a twin-jet and another a triple-jet arrangement. The primary objective is to identify the merits and weaknesses of Reynolds-stress modelling, in contrast to one based on the isotropic eddy-viscosity approach, in the present complex 3D environment. While open questions remain, due principally to uncertainties arising from boundary conditions and insufficient numerical resolution in isolated highly sheared regions the present calculations provide clear indications, in accord with earlier studies in both 2D and 3D flows, of the superiority of the anisotropic closure. It is also demonstrated that a careful treatment of the jet-discharge conditions can be highly influential in respect of predictive realism.
Author

N94-28025# Imperial Coll. of Science and Technology, London (England). Dept. of Chemical Engineering.
PREDICTIONS OF MOMENTUM AND SCALAR FIELDS IN A JET IN CROSS-FLOW USING FIRST AND SECOND ORDER TURBULENCE CLOSURES
J. ALVAREZ, W. P. JONES, and R. SEOUD (Defence Research Agency, London, England.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by Ministry of Defence
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The k-epsilon model and a second moment closure have been applied to the calculation of a slighted heated jet issuing into a cross-flow. Two jet to cross-flow velocity ratios were considered. An assessment of the model performance is made difficult by the high turbulence intensities observed in the recirculation region in the lee of the jet and consequent uncertainty in the hot-wire measurements. Overall, the second moment closure gives slightly better agreement but the difference between the results obtained with the two model is not large. For the low velocity ratio, results are extremely sensitive to the boundary conditions prevailing at jet inlet. The predicted mean temperature profiles appear to be more strongly dependent on the predicted velocity fields than on the scalar field closure.
Author

N94-28026# Middle East Technical Univ., Ankara (Turkey). Dept. of Aeronautical Engineering.
NAVIER-STOKES SIMULATION OF TWO AND THREE DIMENSIONAL JETS IN CROSSFLOW, EFFECTS OF GRID, AND BOUNDARY CONDITIONS
MEHMET SERIF KAVSAOGLU, IBRAHIM SINAN AKMANDOR, SULEYMAN CIRAY (Turkish Aerospace Industries, Ankara.), and KOZO FUJII (Tokyo Univ., Sagamihara, Japan.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 22 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by General Dynamics Corp.
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Flowfields of two and three dimensional subsonic jets injected into a crossflow were solved by using a three dimensional Navier-Stokes code (LANS3D). Baldwin-Lomax turbulence model and the algebraic curved jet turbulence model of Oh and Schetz were used depending on the location in the flowfield. Application of characteristic boundary conditions based on Riemann invariants were found to be useful for the convergence of solutions. Computations made using flat bottom grids showed local pressure singularities around the jet exit. It was shown that these singularities could be removed by using grids with a cavity for the jet entrance. Grid skewness was a particularly effective parameter on the prediction of surface pressures.
Author

N94-28030# Science Applications International Corp., Fort Washington, PA. Propulsive Sciences Div.
RECENT DEVELOPMENTS IN THE SIMULATION OF STEADY AND TRANSIENT TRANSVERSE JET INTERACTIONS FOR MISSILE, ROTORCRAFT, AND PROPULSIVE APPLICATIONS
S. M. DASH, B. J. YORK, N. SINHA, R. A. LEE, A. HOSANGADI, and D. C. KENZAKOWSKI *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 21 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A03/MF A04

A review of recent activities focused on the simulation of transverse jet interaction problems using advanced time-asymptotic and time-accurate Navier-Stokes methodology is presented. Missile work has involved the simulation of short-duration control jets issued from solid rocket motor nozzles. For the simulation of time-accurate particle-laden flows, a new Eulerian-based upwind/implicit particle-solver was developed and coupled with the gas-phase solver. Rotorcraft work has involved simulating the interaction of the exhaust plumes with the rotor wake and body aerodynamic flow. Hybrid vortex tracking/Navier-stokes methodology has been implemented with gridding of this complex 3D interactive flow being an issue of primary concern. Propulsive work has emphasized turbulence modeling. For scramjet fuel-injection applications, compressible-dissipation extensions to the k-epsilon turbulence model which provided marked improvements in simulating fundamental high-speed shear layers, have proven to work quite well for transverse jet injection.
Author

N94-28036# Hertfordshire Univ., Hatfield (England). Dept. of Aeronautics.
EFFECTS OF FREE-STREAM TURBULENCE ON A JET IN A CROSS FLOW
T. H. TOFTEN, A. E. HOLDO, and D. KAPFER *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 10 p (SEE N94-28003 07-34) Nov. 1993 Sponsored by Royal Norwegian Council for Scientific and Industrial Research and Dept. of Scientific and Industrial Research
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

At present there is limited information available on effects of free-stream turbulence intensities and scale on both the time average and instantaneous development of a jet in a cross flow. The aim of this study was to investigate such effects on both entrainment and mean path of the jet using primarily experimental methods. The experimental part consisted of measurements using hot wire anemometers, thermocouples and a nine hole vortex probe as well as observations with a color Schlieren system on a jet issuing from a circular aperture in a flat plate. The jet Reynolds numbers of the tests were in the region 2x10(exp 4) to 8x10(exp 4) and the flow could be considered as incompressible for all cases tested. The use of both visualization technique as well as quantitative measurements have proven to be helpful in the description of free-stream turbulence effects. Although it should

be noted that some quantitative data can be inferred from the Schlieren observations. The results show that there are clear effects due to variations in free-stream turbulence on the development of the jet. The effects within the range of variation in free-stream turbulence intensity and length scale of the investigation are manifest in terms of all main jet characteristics. These characteristics are the rate of entrainment, the mean jet path and the strength of the main jet vortices. The observed effects are significant, but at present there are no direct trends in the results with increasing or decreasing turbulence scales or intensity to help propose the primary mechanisms involved in the effects. This is the subject of further investigations at the present time. Author

N94-28038# Turkish Aerospace Industries, Ankara (Turkey).
NAVIER-STOKES ANALYSIS OF A SWIRLING JET IN CROSSFLOW
HUSEYIN YAGCI and MEHMET SERIF KAVSAOGLU (Middle East Technical Univ., Ankara, Turkey.) *In* AGARD, Computational and Experimental Assessment of Jets in Cross Flow 7 p (SEE N94-28003 07-34) Nov. 1993
(AGARD-CP-534) Copyright Avail: CASI HC A02/MF A04

Flowfield of a subsonic swirling jet injected into a subsonic crossflow was computed by using a three dimensional Navier-Stokes code (LANS3D). Baldwin-Lomax turbulence model and the algebraic curved jet turbulence model of Oh and Schetz were used depending on the location in the flowfield. Characteristic boundary conditions based on Riemann invariants were utilized for the flow in and out planes. A single block grid with a cavity at the jet entrance was used. Author

N94-29280*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL STUDIES ON EFFERVESCENT ATOMIZERS WITH WIDE SPRAY ANGLES
J. D. WHITLOW (Purdue Univ., West Lafayette, IN.), A. H. LEFEBVRE (Purdue Univ., West Lafayette, IN.), and R. J. ROLLBUHLER *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 11 p (SEE N94-29246 08-25) Sep. 1993
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

An experimental investigation was conducted to examine the operating and spray characteristics of two internal-mixing twin-fluid atomizers that were designed to produce effervescent atomization at low air/liquid mass ratios (ALR's). These two experimental atomizers ejected the two phase flow so as to produce a wide spray angle. One atomizer was a plain orifice design that used a four-hole exit orifice which divided and turned the two phase flow just prior to ejection. The other atomizer, called the conical sheet atomizer, ejected the two phase flow through an annular passage in such a way as to form a hollow cone spray. The atomizer operating parameters varied during this investigation were the air/liquid mass ratio, atomizer operating pressure, and, in the case of the conical sheet atomizer, the exit gap width. Studies of spray characteristics included measurements of the spray Sauter mean diameter (SMD), drop size distribution, and, for the conical sheet atomizer, circumferential distribution of the liquid mass within the spray. For both atomizers it was found that SMD decreases with an increase in either ALR or operating pressure. The effect of ALR on SMD diminishes as the value of ALR increases. For the conical sheet atomizer, when operating at low values of pressure and ALR, SMD increases with increase in gap width, but the influence of gap width on SMD diminishes with an increase in either pressure or ALR. At the highest operating pressure of the conical sheet atomizer (552 kPa), SMD is independent of gap width at all ALR's. For both atomizers, changes in operating pressure and ALR have little effect on the distribution of drop sizes in the spray. Author (revised)

N94-29282# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. for Propulsion Technology.
INVESTIGATION OF THE TWO-PHASE FLOW IN A RESEARCH COMBUSTOR UNDER REACTING AND NON-REACTING CONDITIONS
C. HASSA, A. DEICK, and H. EICKHOFF *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 12 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by TECFLAM
(AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

The flow resulting from an airblast atomizer with prefilmer and corotating swirl was investigated in a cylindrical combustion chamber. Gas and droplet velocities were measured by a phase Doppler anemometer and species and gas temperature by gas sampling probes respectively, thermoelements at atmospheric conditions and without fuel and air preheat. Because of interference with the liquid phase, the species measurements were restricted to a minimum distance of 40 mm from the atomizer lip. The temperature measurements showed the dominating influence of the external recirculation zone on flame stabilization for the investigated nozzle configuration with a small expansion angle of the swirling flow. The species concentration fields exhibit homogeneous radial profiles at an axial distance of 100 mm behind the atomizer, although droplets are observed up to 140 mm. Integrating the measured liquid volume flux density profiles, it was found that the fuel flux at 45 mm behind the atomizer had diminished to 14 percent of the maximum measured value. The axial profile of the liquid flux weighted Sauter mean diameter is almost linearly increasing from 22 to 31 micrometers. Systematic experimental errors and losses of the system sensitivity, which enter the results partly with opposite signs, have an influence on the measured flux densities and moments of the particle size distribution. The measurement of individual flux density profiles was reproducible to within 45 percent. A comparison between the gas flow in the nearfield of the atomizer under reacting and nonreacting conditions showed a partial suppression of the expansion of the velocity profiles by the hot corner vortex. Together with the combustion induced axial acceleration, the thus effected reduction of the effective swirl number leads to the breakdown of the recirculation at 29 mm. Author (revised)

N94-29283# Karlsruhe Univ. (Germany). Lehrstuhl und Inst. fuer Thermische Stroemungsmaschinen.
TIME-RESOLVED MEASUREMENTS IN A THREE DIMENSIONAL MODEL COMBUSTOR
R. JECKEL and S. WITTIG *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 15 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by Arbeitsgemeinschaft Hochtemperatur Gasturbine and BMFT
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Locally and time-resolved measurements of the velocity, temperature, and species concentration in a three dimensional jet-stabilized combustor are presented. The combustor was developed at the Institute for Thermal Turbomachinery, University of Karlsruhe, for extended benchmark experiments. For the present investigation, the combustor was fired by propane. The profiles of the velocity, temperature, and species distribution were determined at seven planes along the combustor axis. A comparison between the cold flow and the reacting hot gas conditions is given. The time-resolved velocity and temperature measurements were performed by a two component LDA-system as well as specially designed and optimized thermocouple probes. The time-dependent analysis demonstrates that the velocity and turbulence and/or the temperature fluctuations are dramatically increased under hot combusting conditions. Finally, the locally determined species distributions are compared with the global concentrations at the exit of the combustor providing a data base for numerical tests. Author (revised)

N94-33884# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON PROGRESS IN TRANSITION MODELLING [PROGRES DANS LA MODELISATION DE LA TRANSITION]
Apr. 1994 276 p Special course held in Madrid, Spain, 22-25 Mar. 1993 and in Rhode-Saint-Genese, Belgium, 29 Mar. - 1 Apr. 1993
(AD-A283337; AGARD-R-793; ISBN-92-835-0742-8) Copyright Avail: CASI HC A13/MF A03

Lecture notes for the AGARD Fluid Dynamics Panel (FDP) Special Course on 'Progress in Transition Modelling' have been assembled in this Report. The aim and scope of this Course was to provide information on new developments in modelling the dynamics of transition to turbulence, and the prediction of transition in boundary-layer flows. Specifically, topics and methods covered include: a physical description of boundary-layer transition, linear theory, asymptotic techniques, parabolized stability equations, direct numerical simulations, empirical methods and closure of the Reynolds' averaged Navier-Stokes equations. The material assembled in this report was prepared and presented under the combined sponsorship of the AGARD Fluid Dynamics Panel, and the von Karman Institute (VKI) for Fluid Dynamics. For individual titles, see N94-33885 through N94-33890.

N94-33885*# Arizona State Univ., Tempe, AZ. Dept. of Mechanical and Aerospace Engineering.
PHYSICAL DESCRIPTION OF BOUNDARY-LAYER TRANSITION: EXPERIMENTAL EVIDENCE
WILLIAM S. SARIC *In* AGARD, Special Course on Progress in Transition Modelling 51 p (SEE N94-33884 10-34) Apr. 1994
(Contract(s)/Grant(s): NAG1-1111; AF-AFOSR-0234-90)
(AGARD-R-793) Copyright Avail: CASI HC A04/MF A03

The problems of understanding the origins of turbulent flow and transition to turbulent flow are the most important unsolved problems of fluid mechanics and aerodynamics. It is well known that the stability, transition, and turbulent characteristics of bounded shear layers are fundamentally different from those of free shear layers. Likewise, the stability, transition, and turbulent characteristics of open systems are fundamentally different from those of closed systems. Because of the influence of indigenous disturbances, surface geometry and roughness, sound, heat transfer, and ablation, it is not possible to develop general prediction schemes for transition location and the nature of turbulent structures in boundary-layer flows. At the present time no mathematical model exists that can predict the transition Reynolds number on a flat plate. The recent progress in this area is encouraging, in that a number of distinct transition mechanisms have been found experimentally. The theoretical work finds them to be amplitude and Reynolds-number dependent. The theory remains rather incomplete with regard to predicting transition. Amplitude and spectral characteristics of the disturbances inside the laminar viscous layer strongly influence which type of transition occurs. The major need in this area is to understand how freestream disturbances are entrained into the boundary layer, i.e., to answer the question of receptivity. We refer receptivity to the mechanism(s) that cause freestream disturbances to enter the boundary layer and create the initial amplitudes for unstable waves.
Derived from text

N94-33886# Centre d'Etudes et de Recherches, Toulouse (France). Dept. of Aerothermodynamics.
BOUNDARY LAYER TRANSITION: PREDICTIONS BASED ON LINEAR THEORY
DANIEL ARNAL *In* AGARD, Special Course on Progress in Transition Modelling 63 p (SEE N94-33884 10-34) Apr. 1994
(AGARD-R-793) Copyright Avail: CASI HC A04/MF A03

The objective of this paper is to discuss the possibilities of transition prediction by using the eigenvalues of the classical linear stability equations. Emphasis is placed on the e(sup n) method, with applications to two- and three-dimensional flows. It is shown that the value of the n factor at the onset of transition depends on the disturbance environment. On swept wings, it depends also on the procedure which is adopted to integrate the growth rates. In spite of its shortcomings (the receptivity and the nonlinear processes are not accounted for), the e(sup n) method is useful for parametric studies. Applications to the attachment line flow and to the Gortler instability are also presented. Author

N94-33887# Cambridge Univ., Cambridge (England).
ASYMPTOTIC APPROACHES TO TRANSITION MODELLING
STEPHEN J. COWLEY and XUE-SONG WU *In* AGARD, Special Course on Progress in Transition Modelling 38 p (SEE N94-33884 10-34) Apr. 1994
(AGARD-R-793) Copyright Avail: CASI HC A03/MF A03

The linear and nonlinear evolution of unstable disturbances in high-Reynolds-number flows is reviewed from the perspective of asymptotic theory. For non-parallel and/or unsteady flows, quasi-parallel and quasi-steady approximations can only be strictly justified by asymptotic expansions based on the smallness of the inverse Reynolds number. Further, such an asymptotic approach allows the inclusion of nonlinear effects in a self-consistent manner. Attention is focussed primarily on three asymptotic regions: the lower-branch Tollmien-Schlichting (TS) scaling for boundary layers, the upper-branch TS scaling for boundary layers, and the Rayleigh scaling for (decelerating) boundary layers, free shear layers, jets and wakes. For fixed frequency disturbances in a decelerating boundary layer, these asymptotic regions occur at increasing distances from the leading edge. A disturbance propagating downstream from the leading edge will pass through each region in turn. The larger the initial disturbance, the further upstream nonlinear effects must be taken into account. Weakly nonlinear theory is possible when the relative growth-rate of disturbances is small, e.g. near a neutral curve. Close to the lower branch, it is possible to take into account non-parallelism, wavetrain modulation (i.e. wavepackets), and three dimensional effects such as those that lead to TS-wave/vortex interactions. A number of different models are described and critically assessed. Similar possibilities are examined on the upper-branch scaling, where an additional feature is the effect of nonlinear critical layers. Critical layers play a preeminent role on the Rayleigh scaling. Physical effects explained include the nonlinear saturation of two-dimensional disturbances in free shear layers and decelerating boundary layers, the explosive growth in amplitude of three dimensional disturbances, and the generation of surprisingly large longitudinal vortices and spanwise-dependent mean flows. Author

N94-33888*# Ohio State Univ., Columbus, OH. Dept. of Mechanical Engineering.
PARABOLIZED STABILITY EQUATIONS
THORWALD HERBERT (DynaFlow, Inc., Columbus, OH.) *In* AGARD, Special Course on Progress in Transition Modelling 34 p (SEE N94-33884 10-34) Apr. 1994
(Contract(s)/Grant(s): NAS3-26602; NAS2-13513; F49620-92-J-0271; F33615-90-C-3009; N00014-90-J-1520; AF-AFOSR-0262-91)
(AGARD-R-793) Copyright Avail: CASI HC A03/MF A03

The parabolized stability equations (PSE) are a new approach to analyze the streamwise evolution of single or interacting Fourier modes in weakly nonparallel flows such as boundary layers. The concept rests on the decomposition of every mode into a slowly varying amplitude function and a wave function with slowly varying wave number. The neglect of the small second derivatives of the slowly varying functions with respect to the streamwise variable leads to an initial boundary-value problem that can be solved by numerical marching procedures. The PSE approach is valid in convectively unstable flows. The equations for a single mode are closely related to those of the traditional eigenvalue problems for linear stability analysis. However, the PSE approach does not exploit the homogeneity of the problem and, therefore, can be utilized to analyze forced modes and the nonlinear growth and interaction of an initial disturbance field. In contrast to the traditional patching of local solutions, the PSE provide the spatial evolution of modes with proper account for their history. The PSE approach allows studies of secondary instabilities without the constraints of the Floquet analysis and reproduces the established experimental, theoretical, and computational benchmark results on transition up to the breakdown stage. The method matches or exceeds the demonstrated capabilities of current spatial Navier-Stokes solvers at a small fraction of their computational cost. Recent applications include studies on localized or distributed receptivity and prediction of transition in model environments for realistic engineering problems. This report describes the basis, intricacies, and some applications of the PSE methodology. Author

N94-33889*# Arizona State Univ., Tempe, AZ. Dept. of Mechanical and Aerospace Engineering.
DIRECT NUMERICAL SIMULATION OF TRANSITION: THE SPATIAL APPROACH
HELEN L. REED *In* AGARD, Special Course on Progress in Transition Modelling 46 p (SEE N94-33884 10-34) Apr. 1994
Sponsored by NASA. Langley Research Center; AFOSR; and NSF
(AGARD-R-793) Copyright Avail: CASI HC A03/MF A03

The objective of this paper is to review the efforts in spatial direct numerical simulations for transition modeling. Much recent success has been realized in the development of more efficient numerical algorithms as well as a robust downstream boundary condition. Efforts at explaining complex physical phenomena through the use of simulations are reviewed. Author

N94-33890*# High Technology Corp., Hampton, VA.
MODELING THE TRANSITION REGION
BART A. SINGER *In* AGARD, Special Course on Progress in Transition Modelling 33 p (SEE N94-33884 10-34) Apr. 1994
(Contract(s)/Grant(s): NAS1-19299)
(AGARD-R-793) Copyright Avail: CASI HC A03/MF A03

The calculation of engineering flows undergoing laminar-turbulent transition presents special problems. Mean-flow quantities obey neither the fully laminar nor the fully turbulent correlations. In addition, local maxima in skin friction, wall temperature, and heat transfer often occur near the end of the transition region. Traditionally, modeling this region has been important for the design of turbine blades, where the transition region is long in relation to the chord length of the blade. More recently, the need for better transition-region models has been recognized by designers of hypersonic vehicles where the high Mach number, the low Reynolds number, and the low-disturbance flight environment emphasize the importance of the transition region. Needless to say, a model that might work well for the transitional flows typically found in gas turbines will not necessarily work well for the external surface of a hypersonic vehicle. In Section 2 of this report, some of the important flow features that control the transition region will be discussed. In Section 3, different approaches to the modeling problem will be summarized and cataloged. Fully turbulent flow models will be discussed in detail in Section 4; models specifically designed for transitional flow, in Section 5; and the evaluation of models, in Section 6.
Derived from text

N94-34447# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. fuer Antriebstechnik.
FLOW FIELD ANALYSIS IN A HIGH PRESSURE RATIO CENTRIFUGAL COMPRESSOR
H. PAK, H. KRAIN, and B. HOFFMANN *In* AGARD, Technology Requirements for Small Gas Turbines 12 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

Detailed experimental and theoretical flow field studies were carried out for a high pressure ratio impeller with a high flow coefficient associated with transonic inlet flow. Experimental data were obtained by using the Laser-Two-Focus velocimetry. A 3D viscous code was applied to calculate the flow field. Comparisons between measured and calculated data are presented for 10 cross flow planes with special attention given to the impeller inlet, which is where the transonic flow occurs. Author (revised)

N94-34448# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). Turbomachinery Dept.
INVERSE DESIGN OF RADIAL FLOW IMPELLERS WITH PRESCRIBED VELOCITY AT HUB AND SHROUD
R. A. VANDENBRAEMBUSSCHE, A. DEMEULENAERE, and J. BORGES *In* AGARD, Technology Requirements for Small Gas Turbines 9 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

The method described in this paper allows the detailed design of a complete radial impeller geometry starting from a prescribed suction and pressure side velocity distribution at the hub and shroud. The average velocity at the hub and shroud is used to define the meridional contours. The corresponding blade loading is used to define the blade shape at the hub and shroud. Impellers designed with this method were analyzed by a quasi 3D finite element analysis method. Results show good agreement between the imposed and the calculated Mach number distribution. The method was complemented with an inverse Euler solver capable of designing shock free transonic blades on the previously defined axisymmetric streamsurface. Compared to other inverse methods, this one has the advantage of starting from the velocity distribution itself and requires only a small amount of computer time.
Author (revised)

N94-34450# BMW Rolls-Royce AeroEngines G.m.b.H., Lohholf (Germany).
AERODYNAMIC DESIGN AND INVESTIGATION OF A MIXED FLOW COMPRESSOR STAGE
GERNOT EISENLOHR and FRIEDRICH WILHELM BENFER *In* AGARD, Technology Requirements for Small Gas Turbines 8 p (SEE N94-34431 10-07) Mar. 1994 Sponsored by BMFT
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

Topic of this contribution is a single stage mixed flow compressor with 6:1 pressure ratio, which is under development as a component for a turbojet. Primary design aim for the stage was to achieve minimum frontal area at a high efficiency level. Excerpts of the considerations and calculations for determining the design rotational speed and the main dimensions of this mixed flow compressor stage are presented first. Some explanations concerning the definition of the meridional contours and the generation of the blading are given, supplemented by several results of the impeller flow calculations. After a brief description of the test rig and its instrumentation, the measured impeller characteristics are presented. They show that the impeller meets its design pressure ratio and exceeds the efficiency target. For selected operating points the measured pressure distributions along the impeller outer contour are compared with the predicted static pressure rise. The discussions of the test results closes with the measured mixed flow compressor map which reveals that the overall stage performance does not fully meet the design goals, mainly because of high losses in the diffusing system.
Author (revised)

N94-34451# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. fuer Antriebstechnik.
DESIGN AND ANALYSIS OF A HIGHLY LOADED TRANSONIC COMPRESSOR CASCADE
E. NICKE, W. STEINERT, A. WEBER, and H. STARKEN *In* AGARD, Technology Requirements for Small Gas Turbines 14 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

Starting from two existing cascades a new one was developed for the same inlet and exit flow conditions but increased pitch to chord ratio: inlet Mach number M(sub 1) = 1.09, flow turning Theta = 14 degrees, and pitch to chord ratio s/c = 0.8. Perspective research goal is the determination of the loading limits of transonic compressor cascades. The design was performed in the direct mode using a two dimensional Euler code coupled iteratively with an integral boundary layer code generating a profile Mach number distribution that avoids boundary layer separation. The experiments in a transonic cascade wind tunnel revealed performance, profile, Mach number distribution, and wake traverse data. A laser, two focus measurement technique was used to analyze the flow field upstream of the cascade and around the leading edge. The experimental results are analyzed by the Euler code. To improve the reliability of experimental as well as numerical inlet flow angle determination, the influence of conventional inlet boundary conditions versus so called nonreflecting boundary conditions was tested and verified using the L2F results.
Author (revised)

N94-34462# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).
NUMERICAL SIMULATION OF AIRFOIL FILM COOLING: A JET IN CROSSFLOW
H. J. SAABAS and A. RIAHI *In* AGARD, Technology Requirements for Small Gas Turbines 13 p (SEE N94-34431 10-07) Mar. 1994
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

A control volume finite difference method based on the work of Rhie in conjunction with a two layer turbulence model has been used to predict mean velocities, turbulent kinetic energy, and film effectiveness profiles downstream of a single round jet normal to cross stream at a mass flux ratio of unity. Computations were obtained for domain discretizations in which (1) the jet velocity,

and turbulent kinetic energy profiles were specified at the inlet to the cross flow, and (2) the jet delivery tube and the cross flow were solved for simultaneously using a multiblock approach. The multiblock solutions were carried out for both a circular and rectangular representation of the jet. The numerical results are compared to experimental measurements available in the open literature. The comparisons indicate that the modeling of the hole as circular or rectangular had only a small influence on the predicted flow field and film effectiveness downstream of the hole. However, when jet inlet profiles are specified (rather than calculated), the resulting flow field predictions show deviations from the multiblock solutions especially in the near hole region. This leads to poor agreement between predicted and observed film effectiveness distributions. Author

N94-36328# Dassault Aviation, Saint-Cloud (France). Div. des Etudes Avancees.
LAMINAR FLOW STUDIES AT DASSAULT AVIATION: CALCULATIONS AND FLIGHT TESTS [ETUDES D'ECOULEMENTS LAMINAIRES CHEZ DASSAULT AVIATION: CALCULS ET ESSAIS EN VOL]
J. C. COURTY, C. BULGUBURE, and D. ARNAL *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 14 p (SEE N94-36321 11-05) Nov. 1993 In FRENCH
(AGARD-CP-547) Copyright Avail: CASI HC A03/MF A03

The tools used at Dassault Aviation to calculate the limits on laminar layers, transition criteria and analyses on linear stability are presented and analyzed as far as their precision but also as far as their effectiveness when they have to be used to optimize the design of aircrafts' wing systems. These calculations were used in the concept of laminar deviation that was tested in the air on a FALCON 50, and in the concept of a wing with an hybrid laminarity that was tested in the air on a FALCON 50 during a second phase, 1987-1990. Author

N95-14127# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
TURBOMACHINERY DESIGN USING CFD [LA CONCEPTION DES TURBOMACHINES PAR L'AERODYNAMIQUE NUMERIQUE]
May 1994 251 p Lecture series held in OH, 24-25 May 1994, in Ankara, Turkey, 6-7 Jun. 1994, and in Munich, Germany, 9-10 Jun. 1994 Original contains color illustrations
(AGARD-LS-195; ISBN-92-835-0749-5) Copyright Avail: CASI HC A12/MF A03

Computational Fluid Dynamics (CFD) has become a major design tool for designers of turbomachinery. The progress in this area is fast, and the use of 3-D methods is becoming increasingly applicable to the design process. This Lecture Series will include: (1) Computational methods for preliminary design and geometry definitions; (2) Methods for computing through-flows, blade-to-blade flows and geometry generation; (3) Optimization strategies; (4) Designing in three dimensions; (5) Code validation, mesh influence on solution accuracy; (6) Turbulence and transition modelling; (7) Comparison of time averaged flow solvers and 3-D unsteady CFD codes; (8) Industrial use of CFD and the points of view of the designers. For individual titles, see N95-14128 through N95-14136.

N95-14131# Vrije Univ., Brussels (Belgium). Dept. of Fluid Mechanics.
CFD METHODOLOGY AND VALIDATION FOR TURBOMACHINERY FLOWS
CH. HIRSCH *In* AGARD, Turbomachinery Design Using CFD 44 p (SEE N95-14127 03-34) May 1994
(AGARD-LS-195) Copyright Avail: CASI HC A03/MF A03

The essential problem today, in the application of 3D Navier-Stokes simulations to the design and analysis of turbomachinery components, is the validation of the numerical approximation and of the physical models, in particular the turbulence modelling. Although most of the complex 3D flow phenomena occurring in turbomachinery bladings can be captured with relatively coarse meshes, many detailed flow features are dependent on mesh size, on the turbulence and transition models. A brief review of the present state of the art of CFD methodology is given with emphasis on quality and accuracy of numerical approximations related to viscous flow computations. Considerations related to the mesh influence on solution accuracy are stressed. The basic problems of turbulence and transition modelling are discussed next, with a short summary of the main turbulence models and their applications to representative turbomachinery flows. Validations of present turbulence models indicate that none of the available turbulence models is able to predict all the detailed flow behavior in complex flow interactions. In order to identify the phenomena that can be captured on coarser meshes a detailed understanding of the complex 3D flow in compressor and turbines is necessary. Examples of global validations for different flow configurations, representative of compressor and turbine aerodynamics are presented, including secondary and tip clearance flows. Author

N95-14132# Pratt and Whitney Aircraft, East Hartford, CT.
UNSTEADY FLOWS IN TURBINES: IMPACT ON DESIGN PROCEDURE
O. P. SHARMA, R. H. NI, and S. TANRIKUT *In* AGARD, Turbomachinery Design Using CFD 27 p (SEE N95-14127 03-34) May 1994 Original contains color illustrations
(AGARD-LS-195) Copyright Avail: CASI HC A03/MF A03

The impact of recent research activities in unsteady flows and flow simulation methods used in the turbine design process are outlined. Results from a number of experimental investigations are described to quantify the effect of unsteadiness on the time-averaged flows in turbines. Results from numerical simulations, obtained by using 3-D unsteady Computational Fluid Dynamics (CFD) codes, are also shown to indicate that some of the unsteady flow features can be fairly accurately predicted. An overall discussion is presented to distinguish flow parameters that can be modeled with existing steady CFD codes, from those that require unsteady codes. Author

N95-14133# Sulzer Innotec A.G., Winterthur (Switzerland). Fluid Dynamics Lab.
THE INDUSTRIAL USE OF CFD IN THE DESIGN OF TURBOMACHINERY
M. V. CASEY *In* AGARD, Turbomachinery Design Using CFD 24 p (SEE N95-14127 03-34) May 1994
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The numerical simulation of the internal flowfield now plays a major role in all turbomachinery aerodynamic designs, from aero-engines to hydraulic turbines and pumps. With the help of CFD codes an experienced designer is able to produce more adventurous, better engineered and more clearly understood designs more rapidly at lower cost. This paper reviews the use of CFD as an engineering tool in modern turbomachinery design from the standpoint of a turbomachinery designer. Particular attention is given to the current limitations with regard to performance prediction. The necessary engineering criteria used by turbomachinery designers to overcome these limitations and to assess the weak points of their designs using CFD flowfield computations are discussed. Examples of the application of these general aerodynamic design criteria to most classes of turbomachines using a variety of different CFD codes are given. Author

N95-14134# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Div. Recherches et Etudes Avancees.
NEW METHODS, NEW METHODOLOGY: ADVANCED CFD IN THE SNECMA TURBOMACHINERY DESIGN PROCESS
CHRISTOPHE VUILLEZ and BERTRAND PETOT *In* AGARD, Turbomachinery Design Using CFD 26 p (SEE N95-14127 03-34) May 1994 Original contains color illustrations
(AGARD-LS-195) Copyright Avail: CASI HC A03/MF A03

CFD tools represent a significant source of improvements in the design process of turbomachinery components, leading to higher performances, cost and cycle savings as well as lower associated risks. Such methods are the backbone of compressor and turbine design methodologies at Snecma. In the 80's, the use of 3D Euler solvers was a key factor in designing fan blades with very high performance level. Counter rotating high speed propellers designed with this methodology reached measured performances very close to their ambitious objective from the first test series. In the late 80's and the beginning of the 90's, new, more powerful methods were rapidly developed and are now

commonly used in the design process: a quasi-3D, compressible, transonic inverse method; quasi-3D and 3D Navier-Stokes solvers; 3D unsteady Euler solvers. As an example, several hundred 3D Navier-Stokes computations are run yearly for the design of low and high pressure compressor and turbine blades. In addition to their modelling capabilities, the efficient use of such methods in the design process comes from their close integration in the global methodology and from an adequate exploitation environment. Their validation, their calibration, and the correlations between different levels of modelling are of critical importance to an actual improvement in design know-how. The integration of different methods in the design process is described. Several examples of application illustrate their practical utilization. Comparisons between computational results and test results show their capabilities as well as their present limitations. The prospects linked to new developments currently under way are discussed. Author

N95-14135# General Electric Co., Cincinnati, OH. Aircraft Engines Div.

THE ROLE OF CFD IN THE DESIGN PROCESS

IAN K. JENNIONS *In* AGARD, Turbomachinery Design Using CFD 34 p (SEE N95-14127 03-34) May 1994

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Over the last decade the role played by CFD codes in turbomachinery design has changed remarkably. While convergence/stability or even the existence of unique solutions was discussed fervently ten years ago, CFD codes now form a valuable part of an overall integrated design system and have caused us to re-think much of what we do. The geometric and physical complexities addressed have also evolved, as have the number of software houses competing with in-house developers to provide solutions to daily design problems. This paper reviews how GE Aircraft Engines (GEAE) uses CFD in the turbomachinery design process and examines many of the issues faced in successful code implementation. Author

N95-14136# Technische Univ., Munich (Germany).

AERO DESIGN OF TURBOMACHINERY COMPONENTS: CFD IN COMPLEX SYSTEMS

KLAUS BROICHHAUSEN *In* AGARD, Turbomachinery Design Using CFD 23 p (SEE N95-14127 03-34) May 1994

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The importance of CFD in the design of turbocomponents is no longer a matter of discussion. Since the fundamental publications of Wu and the first successful attempts to determine the potential 2D flow in blade rows the position of computational fluid dynamics in the design of jet-engine turbocomponents has increased continuously. This mainly has been driven by the two factors 'time' and 'cost'. As a result the design engineer of today can rely on a mature set of numerical approaches for the aerodynamic optimization of turbomachines. This design system is structured differently in the specific companies. Generally, however, an inverse correlation between the complexity of the problem and the complexity of the numerical approach can be observed: The most complex problems rely on relatively simple codes with a big portion of empiricism and vice versa. An overview of the design problems and the application of computational methods is given. Author

N95-14201# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.

A SELECTION OF EXPERIMENTAL TEST CASES FOR THE VALIDATION OF CFD CODES, VOLUME 1 [RECUEIL DE CAS D'ESSAI EXPERIMENTAUX POUR LA VALIDATION DES CODES DE L'AERODYNAMIQUE NUMERIQUE]

Aug. 1994 152 p See also 95N-17846 and diskette supplement AGARD-AR-303-Suppl

(AGARD-AR-303-VOL-1; ISBN-92-836-1002-4) Copyright Avail: CASI HC A08/MF A02

This report presents the results of a study by Working Group 14 of the AGARD Fluid Dynamics Panel. This group was formed to establish an accessible, detailed experimental data base for the validation of Computational Fluid Dynamics (CFD) codes. The thirty nine test cases that are documented cover the subsonic, transonic, and supersonic flow regimes and five classes of geometries. Included in the five classes of geometries are: two dimensional airfoils; three dimensional wings, designed for predominantly attached flow conditions; slender bodies, typical of missile type configurations; delta wings, characterized by a conical type of vortex flow; and complex configurations, either in a geometrical sense or because of complicated flow interactions. The report is presented in two volumes. Volume 1 provides a review of the theoretical and experimental requirements, a general introduction and summary of the test cases, and recommendations for the future. Volume 2 contains detailed information on the test cases. The relevant data of all test cases has been compiled on floppy disks, which can be obtained through National Centers. Author

N95-17847# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Entwurfsaerodynamik.

2-D AIRFOIL TESTS INCLUDING SIDE WALL BOUNDARY LAYER MEASUREMENTS

W. BARTELHEIMER, K. H. HORSTMANN, and W. PUFFERT-MEISSNER *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 11 p (SEE N95-17846 04-02) Aug. 1994

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The data presented in this contribution were obtained in the DLR Transonic Wind Tunnel Braunschweig. The intent of the experiment was to provide data giving information on the development of the TWB-side wall boundary layer in the presence of a typical transonic airfoil model for further investigation of the influence of the side wall boundary layer on 2-D airfoil measurements. For this purpose boundary layer pitot pressure were measured in 13 different side wall positions around the airfoil. Airfoil pressure distributions were obtained in several spanwise positions by sliding the airfoil model in a spanwise direction. The test cases investigated correspond to the design conditions of the airfoil (Ma = 0.73, alpha = 1.5 deg) and to a slow (alpha = 0 deg) and a high (alpha = 3.0 deg) lift value at the same Mach number. For these cases wall pressure distributions were measured on the center slat of the top and bottom walls. Additionally to the pressure measurements some oil flow pictures were made on the upper airfoil surface and the adjacent wind tunnel side wall to get more insight in the structure of the flow. In order to have well defined wind tunnel boundary conditions for the evaluation by computational methods, the slotted top and bottom walls of the test section were closed for these specific tests. This means, of course, that the presented airfoil pressure distributions do not correspond to free flight conditions and are not comparable to wind tunnel results obtained in slotted or perforated transonic test sections. Author

N95-17867# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany). Inst. fuer Stroemungsmechanik.

THREE-DIMENSIONAL BOUNDARY LAYER AND FLOW FIELD DATA OF AN INCLINED PROLATE SPHEROID

H.-P. KREPLIN *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 12 p (SEE N95-17846 04-02) Aug. 1994

(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

A research project on the investigation of three-dimensional boundary layers on inclined bodies of revolution has been carried out. Experimental data for such flows were provided which can be used for the validation of calculation methods and the testing and development of turbulence models for three-dimensional flows. Problems of laminar-turbulent boundary layer separation have been studied for a range of angles of incidence and Reynolds number. Derived from text

N95-17869# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

ELLIPSOID-CYLINDER MODEL

D. BARBERIS *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 11 p (SEE N95-17846 04-02) Aug. 1994

(AGARD-AR-303-VOL-2) Copyright Avail: CASI HC A03/MF A06

The data presented in this contribution were obtained in the F2 subsonic wind tunnel of the ONERA Fauga-Mauzac Center. The objective of this work was to obtain detailed experimental

data on a separated vortex flow. The model shape has been chosen to be as simple as possible in order to facilitate the mathematical modeling. This model has been defined after preliminary studies in a water tunnel. The present document reports the results obtained with an axisymmetric model at incidence. Attention has been focused on the boundary layer evolution in the zone of separation and on the mechanism leading to the formation of a well detached primary vortex. The flow has been investigated in great detail by using several experimental techniques: surface flow visualizations, surface pressure measurements, field explorations by multihole pressure probes, and an LDV system. Derived from text

N95-17871# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

TEST DATA ON A NON-CIRCULAR BODY FOR SUBSONIC, TRANSONIC AND SUPERSONIC MACH NUMBERS

P. CHAMPIGNY *In* AGARD, A Selection of Experimental Test Cases for the Validation of CFD Codes, Volume 2 11 p (SEE N95-17846 04-02) Aug. 1994

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Measurements on a non-circular body were made in ONERA wind tunnels. This body, representative of non-conventional missile shapes, was studied for Mach numbers from 0.4 to 3.0 (S2MA wind-tunnel) and 4.5 (S3MA wind-tunnel), angles of attach up to 20 deg and sideslip angles up to 10 deg, with a free transition. The data base consists of static pressure measurements. The intent of the experiment was to provide data for evaluation of three-dimensional flow computation methods, as part of a research program sponsored by the 'Direction des Recherches, Etudes et Techniques' of the French Ministry of Defense. The flow exhibits large separation regions and strong vortices, even at low angles of attack, due to the particular shape of the body (lenticular cross-section). Author

N95-19018# Central Inst. of Aviation Motors, Moscow (Russia).

ON THE CFD MONOTONE HIGH ACCURACY METHODS

MIKHAIL J. IVANOV, VLADISLAV G. KRUPA, and RAVIL Z. NIGMATULLIN *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 19 p (SEE N95-19017 05-07) Dec. 1994

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Some theoretical fundamentals of monotone high accuracy methods are presented. The conditions for the construction of monotone, total variation diminishing (TVD) and following difference schemes are described. The peculiarities of high accuracy and implicit methods design are given. The typical results of numerical solutions illustrate the principle features of developed computational techniques. Author

N95-19019# Central Inst. of Aviation Motors, Moscow (Russia).

SOLUTION OF NAVIER-STOKES EQUATIONS USING HIGH ACCURACY MONOTONE SCHEMES

VLADISLAV G. KRUPA and MIKHAIL J. IVANOV *In* AGARD, Mathematical Models of Gas Turbine Engines and their Components 16 p (SEE N95-19017 05-07) Dec. 1994

(AGARD-LS-198) Copyright Avail: CASI HC A03/MF A02

Numerical monotone methods for integration of the Reynolds averaged Navier-Stokes equations are presented. These methods employ finite volume formulation, implicit high-order accuracy Godunov type scheme and two-equation (q - omega) turbulence model, based on integration up to the wall. To illustrate the typical peculiarities of these methods the computations of viscous flows in curvilinear ducts, around 2D airfoils and 3D shock-wave boundary layer interaction are considered. Available experimental data are used for verification of the computed results. Author

N95-19153# Science Applications International Corp., Fort Washington, PA.

PREDICTION OF FLUCTUATING PRESSURE AND POWER SPECTRA IN ATTACHED AND SEPARATED COMPRESSIBLE FLOW

A. L. LAGANELLI, K. R. WENTZ (Rohr Industries, Inc., Chula Vista, CA.), and H. F. WOLFE (Rohr Industries, Inc., Chula Vista, CA.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 12 p (SEE N95-19142 05-71) Sep. 1994

(Contract(s)/Grant(s): F33615-87-C-3227)

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A brief review is presented of work by the authors to provide an engineering prediction technique for power intensity (rms fluctuating pressure) and power spectral density (PSD) for attached and separated compressible flow. The review process also considers recent shock/turbulent boundary layer interaction work conducted at the University of Texas at Mach 5. It is shown that prediction techniques are hampered as the result of the requirement to know parameters of flow interactions a priori; in particular, the choice of characteristic length and velocity scales. A technique is presented, based on the Houbolt spectra assumption, that appears to provide engineering solutions to the design resolution of complex flow problems. The method is based on a first moment type of PSD (f.phi(f)/(Rho sub OA)squared) that has a fixed value for attached and separated flows. Moreover, when applying the concept with the Houbolt spectra, an excellent comparison is shown to PSD data for shock/turbulent boundary layer interactions. Author (revised)

N95-19251# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.

WALL INTERFERENCE, SUPPORT INTERFERENCE AND FLOW FIELD MEASUREMENTS [LES EFFETS DE PAROI ET DE SUPPORT ET LES MESURES DES CHAMPS D'ECOULEMENT]

Jul. 1994 439 p In ENGLISH and FRENCH Symposium held in Brussels, Belgium, 4-7 Oct. 1993 Original contains color illustrations

(AGARD-CP-535; ISBN-92-835-0756-8) Copyright Avail: CASI HC A19/MF A04

The 31 papers prepared for the AGARD Fluid Dynamics Panel (FDP) Symposium on 'Wall Interference, Support Interference, and Flow Field Measurements' are contained in this report. In addition, a Technical Evaluator's Report assessing the success of the Symposium in meeting its objectives, and an edited transcript of the General Discussion held at the end of the meeting are also included. The primary objective of this Symposium was to report on recent developments from research and technology programs aimed at reducing test data errors caused by wind tunnel walls, model supports, and intrusive flow field measurement devices. The scope of papers included wall interference correction methods based on measured data at the walls and methods to eliminate wall interference through adaptive and/or ventilated walls, support interference calculations and correction methods, and recent advances in flow field measurement techniques. For individual titles, see N95-19252 through N95-19282.

N95-19252# McDonnell-Douglas Aerospace, Long Beach, CA. Transport Aircraft.

THE CRUCIAL ROLE OF WALL INTERFERENCE, SUPPORT INTERFERENCE AND FLOW FIELD MEASUREMENTS IN THE DEVELOPMENT OF ADVANCED AIRCRAFT CONFIGURATIONS

F. T. LYNCH, R. C. CRITES (McDonnell-Douglas Aerospace, Saint Louis, MO.), and F. W. SPAID (McDonnell-Douglas Aerospace, Saint Louis, MO.) *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 38 p (SEE N95-19251 05-34) Jul. 1994

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The requirements, current technology status, and future needs for methodologies to assess wall and support interference effects, and for flow field measurement capabilities, are addressed from an aircraft industry perspective. The requirement for higher Reynolds number testing, especially for transport aircraft, places a much greater burden on the development of the respective technologies. Accurate wall interference estimation methods, including modeling of the tunnel wall flow, are required to assure that models are sized such that wall effects are correctable.

Limitations of wall-interference correction methodologies, which occur as a consequence of current CFD inadequacies, are addressed. Flow field correction methods, as well as surface pressure correction methods, are covered. Three techniques for estimating model support interference are reviewed, namely, the use of dummy stings in experimental tests, use of empirically-based methods for similar installations, and use of CFD-based methods. The need to design support system concepts that minimize interference, and, in the process, permit the effective application of CFD-based methods, is highlighted. Flow diagnostic techniques needed to permit extrapolation of sub-scale wind-tunnel-measured aerodynamic characteristics to full-scale conditions, and to provide the understanding to allow deficiencies to be addressed and corrected, or to guide the design of improved-performance concepts, are reviewed. Both surface flow measurement/visualization and off-body measurements are considered. Noteworthy results obtained with current intrusive devices are reviewed, but the emphasis for the future is clearly shown to reside with optical, non-intrusive techniques such as pressure sensitive paint, infrared imaging, particle image velocimetry, and Doppler global velocimetry. Author

N95-19257# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). Turbomachinery Dept.
AERODYNAMIC INVESTIGATION OF THE FLOW FIELD IN A 180 DEG TURN CHANNEL WITH SHARP BEND
GUIDO RAU and TONY ARTS *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 8 p (SEE N95-19251 05-34) Jul. 1994
(AGARD-CP-535) Copyright Avail: CASI HC A02/MF A04

The internal cooling of gas turbine blades is generally ensured by secondary air flowing through narrow passages existing inside the airfoils. These internal channels are usually connected by 180 deg turns with sharp bends. The aerodynamic and associated convective heat transfer characteristics observed in this type of geometry are significantly influenced by strong secondary flows and flow separations. The purpose of the present experimental effort is to give a detailed description of some aerodynamic aspects of this particular flow pattern. Detailed measurements of the three-dimensional velocity field were performed by means of a two-component Laser Doppler Velocimeter. The third velocity component was obtained by repeating the measurements at two different orientations of the emitting optics with respect to the test section. Author

N95-19262# Defence Research Agency, Bedford (England).
BOUNDARY-FLOW MEASUREMENT METHODS FOR WALL INTERFERENCE ASSESSMENT AND CORRECTION: CLASSIFICATION AND REVIEW
P. R. ASHILL *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 21 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by Dept. of Trade and Industry
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

The development of methods of determining wind-tunnel wall interference from measurements of the flow at a boundary adjacent to the wind-tunnel walls has required the collaboration of theoreticians and experimenters. After these methods are classified and reviewed, techniques for making the measurements are discussed and the concept of correcting wind-tunnel flows to equivalent free-air conditions is examined. Three classes of method are identified, two needing a model representation ('one-variable' and 'wall-signature' types) and a third needing no simulation of the flow around the model ('two-variable' methods). All three classes are related and the need for accuracy in the model representation in 'one-variable' methods can be relaxed by a suitable choice of 'mixed' boundary conditions. Further work is needed to establish non-intrusive techniques and to develop improved methods for determining the normal component of velocity at or just away from the measurement surface. The need for research to establish allowable limits on variations in wall-induced velocity in the region of the model is highlighted. Author

N95-19263# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany).
WALL CORRECTION METHOD WITH MEASURED BOUNDARY CONDITIONS FOR LOW SPEED WIND TUNNELS
A. KUEPPER *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 10 p (SEE N95-19251 05-34) Jul. 1994
(AGARD-CP-535) Copyright Avail: CASI HC A02/MF A04

In the wind tunnel division of DLR in Braunschweig a wall correction method based on measured boundary conditions was developed. The verification of the method was made with theoretically calculated boundary conditions and with experimental test data. The calculation of the wall interferences from theoretical boundary conditions are in good agreement with exact reference data of the wall interferences. The advantage of the wall pressure correction method is shown by the results of the experimental tests where the measured coefficients of the force and the moments are compared with the corrected coefficients and the coefficients of free-flight. In this comparison the classical correction method is shown too. The wall correction method is easy to use because no information of the model is required and can be applied into an on-line processing. Particular attention should be paid to the wall pressure measurement system because wrong wall pressure data can have an influence on the calculated wall interferences. Author

N95-19264# Aeronautical Research Inst. of Sweden, Bromma. Aerodynamics Dept.
COMPUTATIONAL SIMULATIONS FOR SOME TESTS IN TRANSONIC WIND TUNNELS
NADA AGRELL *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 13 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by FFV and Defence Material Dept.
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

Two large models with swept wings have been investigated in two rather similar tunnels, whose cross sectional areas differ by a factor of 9. The tunnels are configured with slotted walls. The larger of the tunnels has a ventilation of 8.3 percent, while the ventilation of the smaller tunnel has been varied between 4.2 percent and 8.3 percent for this investigation. The blockage of the tested models in the tunnels varied from approximately 0.2 percent to 1.7 percent. For the case with blockage of 1.7 percent the ratio of span to the width (equals to the height) of the tunnel was 0.8. For the configuration blocking 0.6 percent in the larger of the two wind tunnels the comparison of Mach number signatures on the tunnel walls between experiments and computations is very good at both Mach numbers, 0.9 and 0.95, and both angles of attack, 0 and 10 degrees. The position of the 'shock' is very well predicted in the computations. Most of the computational simulations for the model blocking 1.7 percent in the smaller of the two tunnels have so far been performed at Mach number 0.8 and at angles of attack of 0 and 2 degrees. This presentation has been concentrated on Mach number 0.8 and angle of attack of 2 degrees. However, a limited number of comparisons is given for other cases, like Mach number 0.8 with angle of attack 5 degrees and Mach number 0.95 with angle of attack 2 degrees. As can be seen the agreement is excellent for all Mach numbers and related angles of attack that have been investigated. Author

N95-19265# Nangia Associates, Bristol (England).
ESTIMATING WIND TUNNEL INTERFERENCE DUE TO VECTORED JET FLOWS
R. K. NANGIA *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 14 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by Defence Research Agency
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

An important consideration in the testing of aircraft models with vectored jets is the allowance to be made for wind tunnel interference on jet flows. Depending on the cross-section dimensions, the wind tunnel interference, can be particularly severe at high incidences or for high jet velocities and large jet deflections. For assessment of these effects, either 'Wall pressure signature' or 'Direct' methods can be used. The wall pressure methods, although requiring dedicated instrumentation, have the advantage that model flow simulation is not required. The direct methods allow calculations of interference prior to the tests and can therefore assist in optimization of model geometry for a particular wind tunnel. A 'Direct' method for estimating wind tunnel interference due to

jet flows is described. A semi-empirical model of the jet plume, imaged in walls has been used to represent the tunnel constraint. Comparisons with results from a 'wall pressure signature' method are very encouraging. The results emphasize the large magnitudes of effects which can arise, particularly in experiments with 2, 3 or 4 vectoring nozzles on multi-surface aircraft configurations. For 4 nozzles with jet velocity ratio near 10, the vertical velocity flow angle can be near 6 - 8 degrees. The present technique offers the capability of guiding the design of acceptable experiments, or for checking the validity of existing information. Several aspects of future work have been proposed. Author

N95-19266*# Wright Lab., Wright-Patterson AFB, OH. Aero-Instrumentation Group.

DETERMINATION OF SOLID/POROUS WALL BOUNDARY CONDITIONS FROM WIND TUNNEL DATA FOR COMPUTATIONAL FLUID DYNAMICS CODES

THOMAS J. BEUTNER, ZEKI Z. CELIK (Stanford Univ., CA.), and LEONARD ROBERTS (Stanford Univ., CA.) *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 19 p (SEE N95-19251 05-34) Jul. 1994

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A computational and experimental study has been undertaken to investigate methods of modelling solid and porous wall boundary conditions in computational fluid dynamics (CFD) codes. The procedure utilizes experimental measurements at the walls to develop a flow field solution based on the method of singularities. This flow field solution is then imposed as a pressure boundary condition in a CFD simulation of the internal flow field. The effectiveness of this method in describing the boundary conditions at the wind tunnel walls using only sparse experimental measurements has been investigated. Verification of the approach using computational studies has been carried out using an incompressible flow solver. The current work demonstrates this technique for low speed flows and compares the result with experimental data obtained from a heavily instrumented variable porosity test section. Position and refinement of experimental measurements required to describe porous wall boundary conditions have also been considered for application to other porous wall wind tunnels. The approach developed is simple, computationally inexpensive, and does not require extensive or intrusive measurements. It may be applied to both solid and porous wall wind tunnel tests. Some consideration is given to the extension of this method to three dimensions. Author

N95-19273# Aeronautical Research Inst. of Sweden, Bromma.

CALCULATION OF LOW SPEED WIND TUNNEL WALL INTERFERENCE FROM STATIC PRESSURE PIPE MEASUREMENTS

LARS FERNKRANS *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 7 p (SEE N95-19251 05-34) Jul. 1994 Sponsored by FMV

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A wall interference prediction tool based on a boundary condition method is developed. The correction method, based on Green's theorem, gives the interference velocity potential field in the control volume from the velocities on a control surface around the model of interest without the need to model the flow field. The boundary velocities around separated wake flows are measured with static pressure pipes. This is done with both solid and partially open test section walls. The results are used for validation of the tool and to evaluate the possibilities to use static pressure pipes in low speed flows as a means to get the perturbation velocities needed to calculate blockage effects in nonsolid walls cases. This paper also describes some problems in estimating flow properties that are not measured. The results presented show that if the static pressure measurements are made carefully it is possible to resolve small cross flow velocities with the necessary accuracy for the correction method. Author

N95-19275# Tsentralni Aerogidrodinamicheskii Inst., Moscow (USSR). Aerodynamics Dept.

THE TRADITIONAL AND NEW METHODS OF ACCOUNTING FOR THE FACTORS DISTORTING THE FLOW OVER A MODEL IN LARGE TRANSONIC WIND TUNNELS

V. M. NEYLAND *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 10 p (SEE N95-19251 05-34) Jul. 1994

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The report presents a brief review of the investigation methods and results obtained for the key problems of the test procedure in the industrial sub- and transonic TSAGI wind tunnels. Among these are the flow calibration in 'empty wind tunnels', the wall interference minimization, and the interference with supporting devices. These problems can be solved only in the combination of the calculation and theoretical investigations with the tests carried out first in pilot facilities and then in large wind tunnels. As examples are given the results of the flow calibration both in the conventional conditions of a uniform test section flow and in a flow with the side wall boundary layer suction which is typical for two-dimensional model tests. The flow boundary influence is investigated by the calculation and experimental method of corrections which works well at angles of attack up to 50 degrees at $M = 0.9$. Good results are also obtained owing to the application of the adaptive perforation to reduce the wall interference on a large-scale civil plane model (blockage is 3.16 percent). The introduction of corrections for the sting-induced flow distortion over the model afterbody is discussed shortly. Author

N95-19276# Centre d'Etudes et de Recherches, Toulouse (France). Dept. d'Etudes et de Recherches en Aero-Thermodynamique.

ANALYSIS OF TEST SECTION SIDEWALL EFFECTS ON A TWO DIMENSIONAL AIRFOIL: EXPERIMENTAL AND NUMERICAL INVESTIGATIONS [EFFETS LATERAUX DANS UNE VEINE D'ESSAIS AUTOUR D'UN PROFIL D'AILE BIDIMENSIONNEL: ETUDES EXPERIMENTALE ET NUMERIQUE]

J. P. ARCHAMBAUD, J. F. MICHONNEAU, and A. MIGNOSI *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 8 p (SEE N95-19251 05-34) Jul. 1994 In FRENCH

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Sidewall effects affect the pressure field around a 2D airfoil tested in wind tunnel, even on its central section. First, laser measurement results show the 3D boundary condition near sidewalls. Then, another experimental investigation points out on the model the perturbation due to sidewall effects. In the second part a numerical method is described (coupling between inviscid flow and sidewall boundary layer computations) which allows taking into account sidewall effects. Comparisons with experiments are shown. Finally, the numerical method is used to estimate the Mach number correction due to sidewall effects. Author

N95-19277# Office National d'Etudes et de Recherches Aerospatiales, Modane (France). Centre d'Essais de Modane-Avrieux.

CALCULATION OF WALL EFFECTS OF FLOW ON A PERFORATED WALL WITH A CODE OF SURFACE SINGULARITIES [CALCULS DES EFFETS DE PAROIS DANS DES VEINES A PAROIS PERFOREES AVEC UN CODE DE SINGULARITIES SURFACIQUES]

J. F. PIAT *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 12 p (SEE N95-19251 05-34) Jul. 1994 In FRENCH

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Simplifying assumptions are inherent in the analytic method previously used for the determination of wall interferences on a model in a wind tunnel. To eliminate these assumptions, a new code based on the vortex lattice method was developed. It is suitable for processing any shape of test sections with limited areas of porous wall, the characteristic of which can be nonlinear. Calculation of wall effects in S3MA wind tunnel, whose test section is rectangular 0.78 m x 0.56 m, and fitted with two or four perforated walls, have been performed. Wall porosity factors have been adjusted to obtain the best fit between measured and computed pressure distributions on the test section walls. The code was checked by measuring nearly equal drag coefficients for a model

tested in S3MA wind tunnel (after wall corrections) and in S2MA wind tunnel whose test section is seven times larger (negligible wall corrections). Author

N95-20647# Maryland Univ., College Park, MD. CALCE Electronic Packaging Research Center.
LIQUID FLOW-THROUGH COOLING OF ELECTRONIC MODULES
S. SRIDHAR, M. D. OSTERMAN, J. M. CARBONELL (Wright Lab., Wright-Patterson AFB, OH.), and K. E. HEROLD *In* AGARD, Advanced Packaging Concepts for Digital Avionics 6 p (SEE N95-20631 06-06) Oct. 1994 Sponsored by Westinghouse Electric Corp. and AMRL
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Thermal management of future avionics modules will be a critical design issue. New advances in integrated circuit technology and electronic packaging will allow the design of densely populated electronics modules with potential power dissipation levels in excess of 1.0 W/cm(exp 2). While the module power level trend will be to increase, the maximum allowable junction temperature for integrated circuits may be lowered to provide more benign thermal environment for electronics. This negates the use of conventional thermal management techniques in new avionics applications. A number of trade studies were performed to determine which cooling technique would be best suited to meet the anticipated reliability and performance requirements for the year 2005 and beyond. The approaches to module cooling technologies considered were: edge cooled conduction, immersion, and hollow core flow-through. The technology selected was the hollow core flow-through. This paper discusses the results of flow-through cooling investigations on both single-pass cold plates and SEM-E modules. Author

N95-20648# Naval Air Warfare Center, Indianapolis, IN. Aircraft Div.
IMMERSION/TWO PHASE COOLING
JACK JONES and EMMETT PERKOSKI *In* AGARD, Advanced Packaging Concepts for Digital Avionics 11 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

Due to increasing heat dissipation requirements, the need for an advanced cooling technique in current military avionics has been recognized. Immersion cooling with phase change has been demonstrated in a Format E clamshell module as an alternative. This module is capable of dissipating more than 700 Watts. From the development of the Format E clamshell module the AAS&T (Advanced Avionics Subsystems and Technology) Program has begun an effort to utilize the clamshell module in the development of a 3/4 ATR Format E Standard Avionics Enclosure utilizing immersion/change of phase cooling. The power dissipation requirement for the enclosure is 6500 Watts minimum. The cooling medium for both efforts is a Fluorinert (FS-72). The FS-72 is an environmentally safe coolant. As the need for greater heat removal and reliability increases, cooling technology must become more advanced to meet the needs of next generation aircraft. Author

N95-20649# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft Div.
MICROCHANNEL HEAT PIPE COOLING OF MODULES
G. MOSER *In* AGARD, Advanced Packaging Concepts for Digital Avionics 12 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A03/MF A03

The purpose of this presentation is the proposal of a novel, highly sophisticated cooling technique with a promising performance, but with a very early status of development - the microchannel heat pipe cooling. This technique can be directly adapted to the basic idea of Modular Avionics resulting on the hardware side in a modular packaging design with interchangeable modules. Due to the early status of the development and of the basic research some of the very stringent requirements for military airborne equipment are not met yet (or information is missing) like the impact of acceleration and orientation; nevertheless, the normal performance capability is highly compliant with the dramatically increasing local maximum heat densities and total maximum heat dissipations, which are forecast for future avionic applications. The presentation shall highlight the status of the development and the benefits of this technique; the latter is done by a comparison to the well established cooling methods for the module like Liquid Flow Through (LFT) and conduction cooling, in order to provide a clear impression of the cooling capabilities. Especially if the microchannel heat pipe is combined with a micro heat exchanger for the heat transfer off the module, the performance with respect to the maximum local heat density, the most challenging requirement for the future, is high in excess of the LFT method. Author

N95-21061# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
APPLICATION OF DIRECT AND LARGE EDDY SIMULATION TO TRANSITION AND TURBULENCE [L'APPLICATION DE LA SIMULATION DIRECTE ET DE LA SIMULATION DES GROS TOURBILLONS A LA TRANSITION ET A LA TURBULENCE]
Dec. 1994 400 p In ENGLISH and FRENCH The 74th symposium was held in Chania, Greece, 18-21 Apr. 1994 Original contains color illustrations
(AGARD-CP-551; ISBN-92-836-0006-1) Copyright Avail: CASI HC A17/MF A04

The papers prepared for the AGARD Fluid Dynamics Panel (FDP) Symposium on 'Application of Direct and Large Eddy Simulation to Transition and Turbulence', which was held April 1994 in Greece are contained in this report. In addition, a Technical Evaluator's Report assessing the success of the Symposium objectives, and an edited transcript of the General Discussion are also included. In the past two decades significant progress has been made in the numerical simulation of turbulent flows. Vast improvements in speed and memory size of modern supercomputers, and recent progress in simulation algorithms and parallel computation have put us on the threshold of being able to simulate flows in configurations of engineering interest. For individual titles, see N95-21062 through N95-21098.

N95-21062*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DEVELOPMENTS AND APPLICATIONS OF DYNAMIC MODELS FOR LARGE EDDY SIMULATION OF COMPLEX FLOWS
P. MOIN, D. CARATI, T. LUND, S. GHOSAL, and K. AKSELVOLL *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 9 p (SEE N95-21061 06-34) Dec. 1994 Prepared in cooperation with Stanford Univ., CA Sponsored by ONR and AFOSR
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The dynamic modeling procedure for large eddy simulation of turbulent flows is reviewed and recent developments in the theoretical aspects and applications are described. Methods for inclusion of backscatter of energy from small to large scale motions are presented. New formulations of the dynamic procedure are proposed which are optimized based on the subgrid scale flux vector or the energy dissipation rate instead of the subgrid scale stress tensor. Recent results from application of the model to forced isotropic turbulence with an inertial subrange, flow over a backward facing step at Reynolds number of 28000, and flow over a concave curved surface are presented. Author

N95-21063# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium). Dept. of Environmental and Applied Fluid Dynamics.
SUBGRID SCALE MODELS IN FINITE DIFFERENCE SIMULATIONS OF COMPLEX WALL BOUNDED FLOWS
ELIAS BALARAS and CARLO BENOCCI *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 6 p (SEE N95-21061 06-34) Dec. 1994
(Contract(s)/Grant(s): EEC-ERBCHDICT930257)
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04

The dynamic subgrid scale model had been used in the Large Eddy Simulation (LES) of turbulent flow in a straight square duct. The Reynolds numbers considered, (based on the friction velocity and the duct halfwidth), are varying from 150 to 1125. The results obtained are in good agreement with the reference Direct Numerical Simulation (DNS) and experimental data. The accuracy and suitability of the model in high Reynolds number finite difference computations of three dimensional non-equilibrium flows is investigated. The influence of approximate wall boundary conditions in such flow cases is also addressed. Author

N95-21064# Maryland Univ., College Park, MD. Dept. of Mechanical Engineering.
LARGE-EDDY SIMULATION OF ROTATING CHANNEL FLOWS USING A LOCALIZED DYNAMIC MODEL
UGO PIOMELLI and JUNHUI LIU *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 9 p (SEE N95-21061 06-34) Dec. 1994
(Contract(s)/Grant(s): N00014-89-J-1638)
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04

Most applications of the dynamic subgrid-scale stress model use volume- or planar-averaging to avoid ill-conditioning of the model coefficient, which may result in numerical instabilities. A spatially-varying coefficient is also mathematically inconsistent with the model derivation. A localization procedure is proposed here that removes the mathematical inconsistency to any desired order of accuracy in time. This model is applied to the simulation of rotating channel flow, and results in improved prediction of the turbulence statistics. Author

N95-21065*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE ASYMPTOTIC STATE OF ROTATING HOMOGENEOUS TURBULENCE AT HIGH REYNOLDS NUMBERS
KYLE D. SQUIRES (Vermont Univ., Burlington, VT.), JEFFREY R. CHASNOV (Hong Kong Univ. of Science and Technology, Clear Water Bay, Hong Kong.), NAGI N. MANSOUR, and CLAUDE CAMBON (Ecole Centrale de Lyon, France.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 9 p (SEE N95-21061 06-34) Dec. 1994 Prepared in cooperation with Stanford Univ., CA Sponsored in part by the American Society for Engineering Education
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The long-time, asymptotic state of rotating homogeneous turbulence at high Reynolds numbers has been examined using large-eddy simulation of the incompressible Navier-Stokes equations. The simulations were carried out using 128 x 128 x 512 collocation points in a computational domain that is four times longer along the rotation axis than in the other directions. Subgrid-scale motions in the simulations were parameterized using a spectral eddy viscosity modified for system rotation. Simulation results show that in the asymptotic state the turbulence kinetic energy undergoes a power-law decay with an exponent which is independent of rotation rate, depending only on the low-wavenumber form of the initial energy spectrum. Integral lengthscale growth in the simulations is also characterized by power-law growth; the correlation length of transverse velocities exhibiting much more rapid growth than observed in non-rotating turbulence. Author

N95-21066# Technische Hogeschool, Twente (Netherlands). Dept. of Applied Mathematics.
COMPARISON OF DNS AND LES OF TRANSITIONAL AND TURBULENT COMPRESSIBLE FLOW: FLAT PLATE AND MIXING LAYER
BERNARD GEURTS, BERT VREMAN, and HANS KUERTEN *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 14 p (SEE N95-21061 06-34) Dec. 1994
(AGARD-CP-551) Copyright Avail: CASI HC A03/MF A04

We present a priori and a posteriori test results of LES (large eddy simulation) of compressible flow over a flat plate and in a mixing layer. Through a comparison with filtered DNS (direct numerical simulation) data the 'quality' of subgrid-models for the turbulent stress can be assessed. In particular, the scale similarity model of Bardina and the dynamic mixed model arising from a combination of Bardina's model with the Germano eddy-viscosity model show excellent correlations a priori, and give rise to accurate LES simulations a posteriori. Moreover, the filtering approach close to solid walls is considered and the contribution to the filtered equations arising from the non-commutation of the filter operator with the partial derivatives is calculated. It appears, in a priori tests for 2D simulations, that these non-commutation terms can be comparable to the turbulent stress. The scale similarity hypothesis yields models for these terms which show a good correlation. Author

N95-21067# Technische Univ., Munich (Germany). Lehrstuhl fuer Fluidmechanik.
DIRECT NUMERICAL SIMULATION OF TURBULENT FLOW IN A SUDDEN PIPE EXPANSION
C. WAGNER and R. FRIEDRICH *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 11 p (SEE N95-21061 06-34) Dec. 1994
(AGARD-CP-551) Copyright Avail: CASI HC A03/MF A04

Direct numerical simulations (DNS) of fully developed turbulent pipe flow and sudden pipe expansion flow with an expansion ratio of ER = 1.2 have been performed. The former DNS provides inflow conditions for the latter. The upstream Reynolds number, based on friction velocity and pipe diameter is 360 or 6950 based on mean centerline velocity. This is too low a Reynolds number to obtain a universal logarithmic law of the wall. Moreover, transverse curvature effects are observed when the data are compared with DNS data of Kim, Moin, Moser in the plane channel. The reason for these effects is that the streak spacing is of the same order of magnitude as the pipe radius. Hence, the pipe expansion flow will also reflect transverse curvature effects. The mean reattachment length is 10.1 step heights. Instantaneous and statistical flow variables are presented. They give an impression of the complex flow dynamics in the free shear layer, the recirculation and reattachment regions. Author

N95-21068# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SIMULATION OF SEPARATED FLOWS [SIMULATION D'ECOULEMENTS DECOLLES]
B. TROFF, T. H. LE, P. SAGAUT, and LOC TAPHUOC (Centre National de la Recherche Scientifique, Orsay, France.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 10 p (SEE N95-21061 06-34) Dec. 1994 In FRENCH Sponsored by DGA/DRET
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Direct Numerical Simulation and Large Eddy Simulations of separated flows have been carried out using the PEGASE code. The incompressible Navier-Stokes equations are solved using a projection method. The spatial discretization is performed via a hybrid finite difference / finite element approach. Results related to the bidimensional backward facing step provided in DNS at Reynolds numbers up to 800 and in LES at a Reynolds number equal to 11,200 are shown. Author

N95-21069# Technical Univ. of Lisbon (Portugal). Dept. of Mechanical Engineering.
LARGE EDDY SIMULATION OF TURBULENT FLOW OVER A CAVITY
J. C. F. PEREIRA and J. M. M. SOUSA *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 10 p (SEE N95-21061 06-34) Dec. 1994 Original contains color illustrations
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Smagorinsky and structure-function models are applied to the large eddy simulation of the turbulent flow over a cavity at a Reynolds number Re = 63,600. The near-wall flow region is modeled by implementing either a logarithmic law-of-the-wall or an exponential damping function. Results obtained with two values of the Smagorinsky constant, C(sub s) = 0.10 and 0.20, have been compared. Further, the results provided by the mentioned subgrid-scale models are compared with those obtained using the standard kappa-epsilon model. As a basis for the comparison, LDV measurements of mean and fluctuating turbulent quantities are also reported. The computational results have demonstrated that the use of large eddy simulation is clearly rewarding in face of kappa-epsilon model computation, yielding better results employing a similar number of grid nodes. Author

N95-21070# Ruhr Univ., Bochum (Germany). Inst. fuer Thermo- und Fluiddynamik.

LARGE-EDDY SIMULATION OF SEPARATED FLOW IN A RIBBED DUCT

HARALD BRAUN, MARTIN FIEBIG, and NIMAI KUMAR MITRA *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 9 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by Deutsche Forschungsgemeinschaft
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Large-eddy simulation of turbulent channel flows over a one-sided periodically ribbed wall has been performed. Large-scale nonsteady structures have been correlated with the statistical values of the turbulent flow field. It is shown, that high turbulent kinetic energy and vortex shedding appear at the same location. The shedding of vortical structures from the edge of the rib is the dominating turbulent phenomena of the flow. The instantaneous behavior of the large-scale vortical structures is visualized and their interaction with the highly fluctuating recirculation zones is observed. Author

N95-21071*# Georgia Inst. of Tech., Atlanta, GA. School of Aerospace Engineering.

ANALYSIS OF SUBGRID MODELS USING DIRECT AND LARGE-EDDY SIMULATIONS OF ISOTROPIC TURBULENCE

S. MENON and P. K. YEUNG *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 12 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by NASA. Ames Recearch Center
(Contract(s)/Grant(s): N00014-93-1-0342)
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Direct and large eddy simulations of forced and decaying isotropic turbulence have been performed using a pseudospectral and a finite-difference code. Subgrid models that include a one-equation subgrid kinetic energy model with and without a stochastic backscatter forcing term and a new scale similarity model have been analyzed in both Fourier space and physical space. The Fourier space analysis showed that the energy transfer across the cutoff wavenumber k(sub c) is dominated by local interaction. The correlation between the exact and the modeled (by a spectral eddy viscosity) nonlinear terms and the subgrid energy transfer in physical space was found to be quite low. In physical space, a similar correlation analysis was carried out using top hat filtering. Results show that the subgrid stress and the energy flux predicted by the subgrid models correlates very well with the exact data. The scale similarity model showed very high correlation for reasonable grid resolution. However, with decrease in grid resolution, the scale similarity model became more uncorrelated, when compared to the kinetic energy subgrid model. The subgrid models were then used for large-eddy simulations for a range of Reynolds number. It was determined that the dissipation was modeled poorly and that the correlation with the exact results was quite low for all the models. In general, for coarse grid resolution, the scale similarity model consistently showed very low correlation while the kinetic energy model showed a relatively higher correlation. These results suggest that to use the scale similarity model relatively fine grid resolution may be required, whereas, the kinetic energy model could be used even in coarse grid. Author

N95-21072# Milan Univ. (Italy). Dipt. di Ingegneria Aerospaziale.

A CHEAP DNS TOOL FOR TURBULENCE MODELS TESTING

A. BARON and M. QUADRIO *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 10 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by Ministero dell'Univ. e della Ricerca Scientifica e Tecnologica and Consorzio Interuniv. Lombardo per l'Elaborazione Automatica
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The Narrow Channel (NC) assumption, together with a simple although efficient numerical scheme are adopted in order to perform the Direct Numerical Simulation (DNS) of turbulent channel flows at moderate Reynolds numbers with extremely reduced computational resources. Typical results are presented for a constant property fluid, which certify the reliability of the numerical tool and the quality of the simulations. The closure problem of turbulence modeling is then considered and the transport equations for the Reynolds stresses and for the dissipation rate of the turbulence kinetic energy are solved on the basis of the Narrow Channel data. The comparison of the distributions of the various terms in the transport equations with published full channel DNS data confirms that, although the NC assumption substantially reduces the computational cost of the simulations, it does not affect the accuracy of the numerical predictions. Finally, as an example of the use that can be done of the numerical tool, an algebraic stress model and a one-equation model for the dissipation rate tensor for low Reynolds number flows are considered, and the modeled quantities are compared with their directly computed counterparts. Author

N95-21073# Det Norske Veritas, Hovik (Norway).

DIRECT SIMULATION OF TURBULENT FLOW IN A SQUARE DUCT: REYNOLDS-STRESS BUDGETS

ASMUND HUSER, SEDAT BIRINGEN (Colorado Univ., Boulder, CO.), and FERHAT F. HATAY (Colorado Univ., Boulder, CO.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 12 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by Fulbright Foundation, Norwegian Space Agency, and Royal Norwegian Council for Scientific and Industrial Research
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The data base from a direct numerical simulation of turbulent flow in a square duct is used to calculate all the terms in the Reynolds stress transport equations. The simulation of this complex turbulent flow was performed at a Reynolds number of 600 based on the friction velocity and the duct width. The distributions of the Reynolds stress budget terms along the wall bisector show similar dynamics to wall-bounded turbulent flows with one inhomogeneous direction. Budget terms in the vicinity of the corner demonstrate how transport and redistribution of energy and shear stresses between the Reynolds stress components takes place, promoting the turbulence characteristics of secondary flows of the second kind. The redistribution of energy by pressure velocity correlations can be explained by the low pressures at the cores of streamwise vortices. The data base is also used to evaluate a nonlinear turbulence model in its ability to accommodate the anisotropy of the Reynolds stress tensor in this flow. This anisotropy is known to be entirely responsible for the formation of the secondary flow in noncircular ducts and cannot be captured by linear models. Author

N95-21074*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

NUMERICAL SIMULATION OF SUPERSONIC BOUNDARY LAYER TRANSITION

Y. GUO (Eidgenoessische Technische Hochschule, Zurich, Switzerland.), N. A. ADAMS, N. D. SANDHAM (Westfield Coll., London, England.), and L. KLEISER (Eidgenoessische Technische Hochschule, Zurich, Switzerland.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 12 p (SEE N95-21061 06-34) Dec. 1994 Prepared in cooperation with Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany
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The present contribution reviews some of the recent progress obtained at our group in the direct numerical simulation (DNS) of compressible boundary layer transition. Elements of the different simulation approaches and numerical techniques employed are surveyed. Temporal and spatial simulations, as well as comparisons with results obtained from Parabolized Stability Equations, are discussed. DNS results are given for flat plate boundary layers in the Mach number range 1.6 to 4.5. A temporal DNS at Mach 4.5 has been continued through breakdown all the way to the turbulent stage. In addition results obtained with a recently developed extended temporal DNS approach are presented, which takes into account some nonparallel effects of a growing boundary layer. Results from this approach are quite close to those of spatial DNS, while preserving the efficiency of the temporal DNS. Author

N95-21075# Institut de Mecanique de Grenoble (France).
SIMULATION OF LARGE SCALE TRANSITIONAL FLOWS [SIMULATION DES GRANDES ECHELLES D'ECOULEMENTS TRANSITIONNELS]
P. COMTE, F. DUCROS, J. SILVESTRINI, E. DAVID, E. LAMBALLAIS, O. METAIS, and M. LESIEUR *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 12 p (SEE N95-21061 06-34) Dec. 1994 In FRENCH
(AGARD-CP-551) Copyright Avail: CASI HC A03/MF A04

Two new subgrid-scale models of turbulence are proposed on the basis of a 2nd-order velocity structure function model developed by Metais and Lesieur. They result from two different approaches aimed at preventing fluctuations at large scales from bringing about turbulent viscosity. Simulations of boundary layers at Mach 0.5 are presented showing that these two models make it possible to simulate the transition to a turbulent regime developed at moderate computational costs in appreciably different configurations (adiabatic plate and strongly heated dihedral). Transl. by CASI

N95-21076# Naval Research Lab., Washington, DC. Remote Sensing Div.
LARGE EDDY SIMULATION OF CHANNEL FLOW USING A VORTICITY TRANSPORT SUBGRID MODEL
AMY L. ROVELSTAD, ROBERT A. HANDLER, PETER S. BERNARD (Maryland Univ., College Park, MD.), and JAMES M. THOMAS (Maryland Univ., College Park, MD.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 7 p (SEE N95-21061 06-34) Dec. 1994 Sponsored in part by NAS-NRC
(Contract(s)/Grant(s): N00014-91-WX-24079; N00014-93-1-0184)
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Vorticity transport concepts are applied to large eddy simulation (LES) techniques in two different contexts. In the first example, the LES equations of motion are reformulated by applying a spatial filter to the rotational rather than the momentum form of the Navier-Stokes equation, leading to the introduction of a subgrid-scale (SGS) vorticity flux tensor. A model originally developed using ensemble averaging is proposed and tested locally and instantaneously using simulations of full channel flow and a minimal channel calculation. The modeled and exact vorticity fluxes are found to generally agree, even for vorticity flux terms which are only present locally and instantaneously. The development of a vorticity transport based wall treatment using a deterministic vortex element approach is also outlined. Initial tests comparing the results of this approach to the zero pressure gradient and stagnation point boundary layer are compared to the Blasius and Falkner-Skan solutions and found to be in good agreement. Author

N95-21077# Ecole Centrale de Lyon (France). Lab. de Mecanique des Fluides et d'Acoustique.
MODELLING ANISOTROPY AND BACKSCATTER EFFECTS IN THE SUBGRID SCALE STRESS TENSOR
T. GOUTORBE and D. LAURENCE (Electricite de France, Chatou, France.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 7 p (SEE N95-21061 06-34) Dec. 1994
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04

A new Subgrid scale (SGS) model used for Large-Eddy Simulation (LES) is developed by extending the scale-similarity hypothesis. Here a conventional Reynolds averaging is used instead of a test filter, resulting using the resolved (large scale) part of the Reynolds stress tensor. This resolved Reynolds stress (RRS) model, without any eddy viscosity assumption, is shown to properly reproduce the drain and backscatter partition of energy exchange between resolved and subgrid scales (for a channel flow at moderate Reynolds numbers). After assessing these properties by a priori tests (filtering DNS results), LES computations are carried out, determining the model constants by an analytical approach and a dynamic approach. In both cases, backscatter effects can lead to instabilities which are finally cured by introducing a transport equation for the SGS energy. This is felt necessary because when backscatter occurs, both SGS production and Kolmogorov dissipation are negative, so SGS energy must vanish, thus ending backscatter. Only a transport equation for the SGS energy can account for this energy conservation principle which is violated by dynamic approaches, that impose an average procedure. Slight discrepancies appear in the buffer layer which may be attributed to the insufficient resolution of streak structures in the spanwise direction. Thus, an adaptation for the buffer-layer appears to be the last obstacle to construct a model accounting for the most important physical properties required for SGS modeling and applicable for practical applications at high Reynolds numbers. Author

N95-21078# Princeton Univ., NJ. Fluid Dynamics Research Center.
SIMULATION OF PIPE FLOW
Y. ZHANG, A. GANDHI, A. G. TOMBOULIDES, and S. A. ORSZAG *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 9 p (SEE N95-21061 06-34) Dec. 1994 Sponsored in cooperation with ARPA
(Contract(s)/Grant(s): N00014-92-J-1796; N00014-92-C-0216)
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In this paper we report simulations of low to moderate Reynolds number turbulent pipe flow, obtained using a 3-D spectral code. Here we describe features of flows at Reynolds numbers Re = 2500 and 4000 and compare with available data. It is noted that simulations with periodic inflow/outflow boundary conditions do not reproduce the turbulent puff and slug flows found in spatially evolving transitional flows. The goal is to coordinate the use of this code with the currently performed SuperPipe experiments now underway at Princeton University. Author

N95-21079*# Aeronautical Research Inst. of Sweden, Bromma.
SIMULATIONS OF BYPASS TRANSITION FOR SPATIALLY EVOLVING DISTURBANCES
A. LUNDBLADH, P. J. SCHMID (Washington Univ., Seattle, WA.), S. BERLIN (Royal Inst. of Tech., Stockholm, Sweden.), and D. S. HENNINGSON *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 13 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by NASA. Langley Research Center
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The spatial evolution of disturbances in plane Poiseuille flow and zero pressure gradient boundary layer flow is considered. For disturbances governed by the linearized equations, potential for significant transient growth of the amplitude is demonstrated. The maximum amplification occurs for disturbances with zero or near zero frequencies. Spatial numerical simulations of the transition scenario involving a pair of oblique waves has been conducted for both flows. A fully spectral solver using a simple but efficient fringe region technique allowed the flows to be computed with high resolution into the fully turbulent domain. A modal decomposition of the simulation results indicates that non-linear excitation of the transient growth is responsible for the rapid emergence of low-frequency structures. Physically, this corresponds to streaky flow structures, as seen from the results of a numerical amplitude expansion. Thus, this spatial transition scenario has been found to be similar to the corresponding temporal one. In the boundary layer simulations the streaks are seen to break down from what appears to be a secondary instability. Author

N95-21080# Universidad Politecnica de Madrid (Spain). School of Aeronautics.
DIRECT NUMERICAL DETERMINATION OF THE MINIMUM BYPASS REYNOLDS NUMBER IN BOUNDARY LAYERS
ROQUE CORRAL and JAVIER JIMENEZ *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 10 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by ESA
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04

It is argued that bypass transition on a flat plate can be interpreted as a consequence of the subcritical nature of the instability of the boundary layer, and that the minimum bypass Reynolds number should coincide with the one at which the turbulent layer relaminarizes spontaneously. This threshold is found by direct numerical simulation of a spatially periodic turbulent layer in which spatial growth is modeled by a linear normal velocity. The computed mean profiles and integral properties agree well with experimental results at the higher Reynolds numbers, but diverge from them at the lower ones. While experiments turn away from the turbulent correlations below Re(sub theta) approx. equals 300 - 500, the computations follow them until relaminarizing abruptly at Re(sub theta) approx. equals 200. The simulations use relatively small periodic computational boxes, holding only a few boundary

layer thickness, and it is argued that this provides enough feedback to prevent the transitional effects observed in experiments and to result in an absolute relaminarization threshold. The Reynolds number obtained in this way agrees with the onset of bypass transition in experiments with very high free stream turbulence levels, or with strong roughness tripping. Author

N95-21083# Stanford Univ., CA. Dept. of Mechanical Engineering.

ENTRAINMENT IN A SHEAR-FREE TURBULENT MIXING LAYER

D. A. BRIGGS, J. H. FERZIGER, J. R. KOSEFF, and S. G. MONISMITH *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 18 p (SEE N95-21061 06-34) Dec. 1994
(Contract(s)/Grant(s): N00014-92-J-1611)
(AGARD-CP-551) Copyright Avail: CASI HC A03/MF A04

Results from a direct numerical simulation of turbulent mixing layer are presented. The flow evolves without shear and the mixing mechanisms associated with the turbulence are isolated. In the first set of simulations the turbulent mixing layer decays as energy is exchanged between the layers. In the second set, a forced mixing layer is simulated by continuously supplying energy to the higher energy side to maintain a stationary kinetic energy profile. Reynolds numbers based on the Taylor microscale of 28 and 38 are obtained in the decaying and forced simulations, respectively. The intermittency of the mixing layer is quantified by calculating the skewness and kurtosis of the velocity fields: results compare well with the shearless mixing layer experiments. Eddies of size of the integral scale (k(exp 3/2)/epsilon) penetrate the mixing layer intermittently, transporting energy and governing the growth rate. The scalar dissipation rate, a measure of the mixing, peaks in the mixing layer. The triple correlation models are applied to the inhomogeneous mixing layer and evaluated. The isotropic models tend to underpredict these correlations by as much as 60 percent while the more complicated anisotropic models are shown to be significantly more accurate. Both models for the pressure strain tensor are also shown to predict values that are incorrect by as much as 50 percent. Author

N95-21084*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

DIRECT SIMULATION OF A SELF-SIMILAR PLANE WAKE

ROBERT D. MOSER and MICHAEL M. ROGERS *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 8 p (SEE N95-21061 06-34) Dec. 1994
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04

Direct simulations of two time-developing turbulent wakes have been performed. Initial conditions for the simulations were obtained from two realizations of a direct simulation of a turbulent boundary layer at momentum thickness Reynolds number 670. In addition, extra two-dimensional disturbances were added in one of the cases to mimic two-dimensional forcing. The unforced wake is allowed to evolve long enough to attain self-similarity. The mass-flux Reynolds number (equivalent to the momentum thickness Reynolds number in spatially developing wakes) is 2000, which is high enough for a short kappa(exp -5/3) range to be evident in the streamwise one-dimensional velocity spectrum. Several turbulence statistics have been computed by averaging in space and over the self-similar period in time. The growth rate in the unforced flow is low compared to experiments, but when this growth-rate difference is accounted for, the statistics of the unforced case are in reasonable agreement with experiments. However, the forced case is significantly different. The growth rate, turbulence Reynolds number, and turbulence intensities are as much as ten times larger in the forced case. In addition, the forced flow exhibits large-scale structures similar to those observed in transitional wakes, while the unforced flow does not. Author

N95-21085*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

THE EFFECT OF INITIAL CONDITIONS ON THE DEVELOPMENT OF TEMPORALLY EVOLVING PLANAR THREE DIMENSIONAL INCOMPRESSIBLE WAKES

ROLF SONDERGAARD (Stanford Univ., CA.), NAGI N. MANSOUR, and BRIAN J. CANTWELL (Stanford Univ., CA.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 13 p (SEE N95-21061 06-34) Dec. 1994
(Contract(s)/Grant(s): N00014-90-J-1976)
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A set of direct numerical simulations of temporally evolving incompressible plane wakes started from a variety of initial conditions have been performed. The intent is to explore the effect of initial conditions on the development of three dimensionality. It was found that the existence of an oblique disturbance at a streamwise wavelength equal to the two-dimensional subharmonic wavelength plays a very important role in the development of the wake. The Reynolds number and the presence or absence of longer wavelength disturbances were also found to be important at late times in the development of the flow. Disturbance phase was found to have an effect on the details of the structure of the wake, but has relatively little effect on the wake growth. Author

N95-21086# University of West Bohemia, Plzen (Czechoslovakia).

DIRECT SIMULATION OF TRIDIMENSIONAL WAKE OF NACA 0012 PROFILE [SIMULATION DIRECTE DU SILLAGE TRIDIMENSIONNEL DU PROFIL NACA 0012]

J. DUSEK and PH. FRAUNIE (Universite de Toulon et du Var, France.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 9 p (SEE N95-21061 06-34) Dec. 1994 In FRENCH Sponsored by cooperation with the European program CST PECO - Individual Mobility
(Contract(s)/Grant(s): DGA-91/158)
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Direct numerical simulation of the tridimensional wake developing downstream from a NACA 0012 wing has been performed using the spectral element code NEKTON. The onset of instability in the wake of an infinite NACA 0012 wing is investigated. The first bifurcation is studied in a two dimensional configuration with a mesh obtained using the numerical experience with a two dimensional unstable cylinder wake. The second bifurcation accompanied by the onset of three-dimensionality is simulated on a three dimensional spectral element mesh obtained by extending the two-dimensional mesh spanwise. The onset of three-dimensionality is characterized by a deformation of the downstream and transverse velocity profiles in the spanwise direction and by the onset of an oscillating spanwise velocity. The critical Reynolds numbers are estimated for both bifurcations. The second bifurcation is shown to be characterized by a period doubling, i.e., the Strouhal frequency of the spanwise velocity is rather precisely equal to half the frequency of the transverse velocity oscillations. This result is in agreement with the numerical results of Karniadakis and Triantafyllou obtained for an infinite circular cylinder and confirms indirectly the experimental results of Williams-Stuber and Gharib showing that to obtain a Ruelle and Takens scenario in a wake, an external forcing is needed. Furthermore, simulations in a geometrically three-dimensional configuration of a finite wing are performed. The development of the tip vortex of a finite wing is investigated. Comparisons are made with available experimental results performed at low Reynolds numbers. The structure of the three dimensional flow is found to be in good agreement with experiments. The simulations are carried out at supercritical Reynolds numbers at which the wake is unstable. The wake oscillations and tip vortex oscillations are evidenced and shown to be characterized by roughly the same Strouhal frequency although the computations could not be pushed until relaxation of transients. Author

N95-21087# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
NUMERICAL SIMULATION OF SPATIALLY-DEVELOPING PLANAR JETS
GUY HOFFMANN and CARLO BENOCCI *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 6 p (SEE N95-21061 06-34) Dec. 1994
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04
The flowfield of an impinging jet is investigated numerically by means of the LES technique. The numerical scheme uses a high order upwind biased formulation for the advective transport. A localized dynamic evaluation of the Smagorinsky constant is employed to avoid an empirical tuning of this value. A critical problem is the formulation of open boundary conditions. The set of boundary conditions presented here allows both the entrainment of fluid into the computational domain as well as the exit of the large vortical structures typical for this flow problem. Author

N95-21088# La Sapienza Univ., Rome (Italy). Dipt. de Meccanica e Aeronautica.
RIB VORTICES IN ROUND JETS: DIRECT AND LARGE EDDY SIMULATION
M. FATICA, R. VERZICCO, and P. ORLANDI *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 10 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by Agenzia Spaziale Italiana
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04
Direct and Large Eddy simulations of temporal evolving round jets at low Reynolds numbers have been performed by a second-order finite difference scheme in cylindrical coordinates. The simulations have shown the formation of longitudinal structures whose number increases with the Reynolds number. The role of these structures in the spreading of the jet and in the creation of small scales has been analyzed. LES models (Smagorinsky and dynamic models) permit to have satisfactory results with coarse grids. Author

N95-21089# Ankara Univ. (Turkey). Dept. of Mechanical Engineering.
DIRECT NUMERICAL SIMULATION OF TRANSITION TO TURBULENCE FROM A HIGH-SYMMETRY INITIAL CONDITION
OLUS N. BORATAV and RICHARD B. PELZ (Rutgers - The State Univ., Piscataway, NJ.) *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 9 p (SEE N95-21061 06-34) Dec. 1994
(Contract(s)/Grant(s): AF-AFOSR-0248-91)
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04
The three-dimensional time evolution of a highly symmetrical vortex array is simulated using a Fourier pseudospectral method for Re = 1/nu = 2000 with an effective resolution of 1024(exp 3) collocation points (k(sub max) = 340). It is found that before the peak enstrophy is reached, there is a short stage when the local quantities increase sharply. The velocity derivative skewness and flatness values reach to 0.9 and 80 respectively. It is also found that during this interval, 6 vortex dipoles (at the origin) and 3 dipoles (at the pi/2 corner) collapse towards two separate vorticity null points. The coherent vortices break up afterwards followed by sharp decrease in local quantities possibly due to dissipation. The singularity analysis shows that maximum vorticity scales as (T - T(sub c))(exp -1) shortly before the break up. The temporal evolution of the width of the analyticity strip shows that delta approaches zero but reaches a minimum positive value and starts to increase. This suggests that the solution remains uniformly analytic similar to the viscous Burgers equation. Author

N95-21090*# Arizona State Univ., Tempe, AZ. Dept. of Mechanical and Aerospace Engineering.
DIRECT NUMERICAL SIMULATIONS OF LEADING-EDGE RECEPTIVITY FOR FREESTREAM SOUND
DAVID A. FUCIARELLI and HELEN L. REED *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 8 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by NASA. Langley Research Center and NSF
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04
The objective of this paper is to review our efforts in spatial direct numerical simulations for modeling leading-edge receptivity to freestream sound and vorticity. These results begin to provide the link between the freestream and the initial boundary-layer response and can provide the upstream conditions for further simulations marching through the transition process toward turbulence. Author

N95-21091# Boeing Commercial Airplane Co., Seattle, WA.
NUMERICAL STUDY OF REALISTIC PERTURBATIONS IN THREE-DIMENSIONAL BOUNDARY LAYERS
P. R. SPALART, J. D. CROUCH, and L. L. NG *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 10 p (SEE N95-21061 06-34) Dec. 1994
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04
Direct Numerical Simulation is applied to a variety of small perturbations developing in a three-dimensional boundary layer. The basic flow is independent of the spanwise coordinate but incorporates a favorable and an adverse pressure gradient in the chordwise direction, similar to the leading-edge region of a swept wing. The edge velocity is analytically defined. Both Cross-Flow and Tollmien-Schlichting modes are amplified. Results focus on questions that are often open in three-dimensional transition-predictions codes, particularly 'e(exp N)' type codes. They include: non-parallel effects; choice of wave-vector; choice of propagation velocity and direction; and the effect of broad spectra, in either space direction and/or time. For this we survey a range of perturbations from pure waves to wave packets; the latter result from initial perturbations that are local in both space and time, and are arguably the richest type of disturbance. Quantitative results are offered for the validation of stability codes, and some are compared with Orr-Sommerfeld results. Author

N95-21092# Technische Hogeschool Twente, Enschede (Netherlands). Dept. of Applied Mathematics.
ON SUBCRITICAL INSTABILITY OF THE ATTACHMENT LINE BOUNDARY LAYER
VASSILIOS THEOFILIS *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 8 p (SEE N95-21061 06-34) Dec. 1994
(AGARD-CP-551) Copyright Avail: CASI HC A02/MF A04
Subcritical instability in the two-dimensional incompressible attachment-line boundary layer remains a topic of debate, after the apparently contradictory results of Hall and Malik (1986) on one hand and Spalart (1988) and Jimenez et al. (1990) on the other. Direct Numerical Simulation (DNS) results are presented, aiming at addressing this question. Extensive numerical experimentation has been performed and all results obtained suggest that the two-dimensional model equations describing leading edge boundary layer (LEBL) flow doe not support solutions growing subcritically in Reynolds number, although the nonlinear neutral loop is seen to bifurcate from its linear counterpart in a manner consistent with the predictions of the theory of Hall and Malik (1986). Nonlinear neutral loops have been obtained suggesting that the two-dimensional model LEBL flow is similar to the classical Blasius boundary layer in terms of the location, in parameter space, of the experimentally observed naturally occurring instability waves. Author

N95-21093# Stuttgart Univ. (Germany). Inst. fuer Aerodynamik und Gasdynamik.
SPATIAL DIRECT NUMERICAL SIMULATION OF BOUNDARY LAYER TRANSITION UNDER STRONG ADVERSE PRESSURE GRADIENT
H. BESTEK, M. KLOKER, and W. MUELLER *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 12 p (SEE N95-21061 06-34) Dec. 1994 Sponsored by Deutsche Forschungsgemeinschaft and Stiftung Volkswagenwerk
(AGARD-CP-551) Copyright Avail: CASI HC A03/MF A04
Laminar-turbulent breakdown of a strongly decelerated Falkner-Skan-type boundary layer (Hartree-Parameter beta(sub H)=-0.18) is investigated by direct numerical simulations using the complete Navier-Stokes equations for three-dimensional incompressible flows. The numerical method is based on the so-called spatial model, and allows for simulations of spatially evolving three-dimensional disturbance waves in a two-dimensional growing boundary layer. Transition is initiated by 2-D and a pair of oblique 3-D waves, both with small amplitudes, excited periodically within a narrow disturbance strip at the plate surface. Their streamwise (linear and subsequent nonlinear) evolution resulting in the fundamental breakdown of laminar flow is simulated with

high spatial resolution. It is observed that the fundamental breakdown process under adverse pressure gradient is dramatically more complex than the well-known K-breakdown in the Blasius flow: In addition to the (upper) high-shear layer on top of the lambda-vortex, a (lower) characteristic high-shear layer is formed simultaneously in between neighboring lambda-vortices. This shear layer, induced by a secondary vortex system close to the wall, precipitates ultimate breakdown to turbulence. Finally, some results of preliminary studies on the effect of suction on boundary-layer transition are presented that demonstrate the great potential of spatial direct numerical simulations for applied transition research in flows of practical interest. Author

N95-21094*# Arizona Univ., Tucson, AZ. Dept. of Aerospace and Mechanical Engineering.

NAVIER-STOKES SIMULATIONS OF THE EFFECTS OF SUCTION HOLES ON A FLAT PLATE BOUNDARY LAYER

HUBERT L. MEITZ and HERMANN F. FASEL *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 10 p (SEE N95-21061 06-34) Dec. 1994

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Direct numerical simulations (DNS) of the Navier-Stokes equations are employed to explore the effects of suction holes on transition in a laminar flat plate boundary layer. The Navier-Stokes equations are cast in vorticity-velocity form. Periodicity is imposed in spanwise direction; all other spatial derivatives are discretized with fourth order compact differences. An explicit fourth order Runge-Kutta scheme is employed for the time-integration of the vorticity transport equations. Suction is applied through a row of holes aligned in spanwise direction. For low suction strengths, each hole generates a pair of stable streamwise vortices. When the suction strength exceeds a critical value, the vortices become unstable. For high suction strengths, vortex shedding occurs right at the suction holes. Our numerical findings agree well with experimental observations. Author

N95-21095# Stuttgart Univ. (Germany). Inst. fuer Aerodynamik und Gasdynamik.

DIRECT NUMERICAL SIMULATION OF 2-D AND 3-D INSTABILITY WAVES IN A LAMINAR SEPARATION BUBBLE

ULRICH RIST and ULRICH MAUCHER *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 7 p (SEE N95-21061 06-34) Dec. 1994

(Contract(s)/Grant(s): DFG-RI-680/1-1)

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Direct Numerical Simulations of a laminar separation bubble are presented, where the bubble is generated by prescribing a locally decelerated free-stream velocity along a flat-plate. Controlled disturbances are introduced into the flow field upstream of the bubble by suction and blowing through the wall in order to study the linear and nonlinear stability characteristics of the flow. A number of generic cases with different two-dimensional (2-D) and three-dimensional (3-D) initial disturbance amplitudes are investigated: (1) a linear case; (2) a case subject to secondary instability (strong amplification of 3-D disturbances by resonance with a large amplitude 2-D wave); (3) a 3-D nonlinear case (interaction of two oblique waves); and (4) a nonlinear case combining the interaction of two oblique waves with a 2-D wave. Good quantitative agreement of the numerical results with (local) linear stability theory is observed throughout case (1) and for the initial disturbance development of the priming waves in the other cases despite the nonparallel base flow. For the nonlinear disturbance development development, however, unexpected results are obtained: Secondary instability is hard to distinguish from primary instability and apparently breaks down as soon as the priming 2-D disturbances saturate. However, the nonlinear mechanism identified in cases (3) and (4), is obviously much more likely to produce large amplitude 3-D disturbances necessary for the generation of a transitional laminar separation bubble. The mechanism leads to a nonlinearly saturated regime with reasonably turbulent mean-flow characteristics as well as longitudinal vortices in the reattachment zone. Author

N95-21096# Hellenic Air Force Academy, Athens (Greece). Dept. of Aerodynamics.

INVESTIGATION OF SHEAR LAYER TRANSITION USING VARIOUS TURBULENCE MODELS

J. K. KALDELLIS and G. A. GEORGANTOPOULOS *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 11 p (SEE N95-21061 06-34) Dec. 1994

(AGARD-CP-551) Copyright Avail: CASI HC A03/MF A04

The accurate prediction of shear layer transition plays an important role in the performance amelioration of modern aero-mechanical devices, since transitional shear layers are frequently observed on axial turbomachine blades and other low Reynolds number airfoils. In the present work some of the most famous existing turbulence models are used in order to analyze a large variety of well documented experimental transitional shear flows. Particular attention is paid to the estimation of the transition length and to the calculation of loss evolution inside the transition area. Finally interesting conclusions of the proposed analysis are summarized in the last part of the paper, where the behavior of several transitional blade shear layers is examined, applying the most reliable of the above tested turbulence models. Author

N95-21097# Groningen Rijksuniv. (Netherlands). Dept. of Mathematics.

DNS OF TURBULENT FLOW IN A DRIVEN CAVITY AND THEIR ANALYSIS USING PROPER ORTHOGONAL DECOMPOSITION

W. CAZEMIER, R. W. C. P. VERSTAPPEN, and A. E. P. VELDMAN *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 11 p (SEE N95-21061 06-34) Dec. 1994

(AGARD-CP-551) Copyright Avail: CASI HC A03/MF A04

Direct Numerical Simulation (DNS) of 2D and 3D lid-driven cavity flows have been performed. The results have been analyzed using Proper Orthogonal Decomposition (POD). POD has been applied to a 2D driven cavity at Reynolds number 22,000 and to a 3D at Re = 10,000. The POD-basis-functions have been computed using the so-called 'snapshot' method of Sirovich. The 2D basisfunctions are used for a Galerkin projection of the Navier-Stokes equations. This results in a relatively low (20 to 80) dimensional dynamical behavior, that shows (almost) the same dynamical behavior, in short and long term, as the DNS. Moreover, if the Reynolds number is set to 11,000, the 80-dimensional dynamical system has (almost) the same periodic solution as the 2D Navier-Stokes equations have at Re = 11,000. Author

N95-21098# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

DIRECT SIMULATION AND GRAPHICS POST-PROCESSING OF THREE-DIMENSIONAL TURBULENT FLOWS

J. RYAN, P. LEONCINI (Italian Aerospace Research Center, Capua.), U. BERRINO (Italian Aerospace Research Center, Capua.), and B. TROFF *In* AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence 6 p (SEE N95-21061 06-34) Dec. 1994

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Direct Simulations involve huge amounts of time dependent data and are expensive to run fully even on supercomputers. A thousand hours of CRAY to obtain valid results is in the order of things. Such costs can be significantly reduced by MIMD machines. To be able to analyze the computed results many and various visualization techniques are also essential. This paper presents work that was done at ONERA to parallelize a Navier-Stokes solver PEGASE and development of an interactive visualization tool at CIRA applied to numerical turbulent flow fields generated by the solver. This work was partly achieved within the framework of the European RACE/PAGEIN project which was aimed at demonstrating the feasibility of Direct Numerical Simulation techniques for future industrial developments, implying modern supercomputer technology, high performance computing networking and massive data transfers between vector and/or parallel supercomputers. The first part of this paper presents the essential characteristics of version 1.0 of PEGASE implemented on a vector machine, the second part describes modifications in algorithms and coding in order to implement it efficiently on the IPSC860 and on a PARAGON. Numerical results and comparisons in costs between the three machines are given. The third part

describes the graphics post-processing developed at CIRA.
Author

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INSTRUMENTATION AND PHOTOGRAPHY

Includes remote sensors; measuring instruments and gages; detectors; cameras and photographic supplies; and holography.

N92-22815# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Inst. of Optoelectronics.
COMPACT LASER DOPPLER ANEMOMETER
CH. WERNER, M. KLIER, H. HERRMANN, E. BISELLI, and R. HAERING *In* AGARD, Remote Sensing of the Propagation Environment 7 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Wind profiles in the atmospheric boundary layer are a very important parameter in the study of atmospheric exchange processes. A small laser Doppler anemometer was designed, constructed, and tested. The system consists of the laser Doppler anemometer mounted on a pedestal and controlled by a personal computer. A sine wave fitting computer program is used to get the wind velocities and wind direction for the selected levels. This sophisticated program can distinguish between cloud and aerosol signals and also uses the azimuthal angle-velocity for extracting the direction of the wind. D.R.D.

N92-28092# Photonetics S.A., Marly-le-Roi (France).
FIBER-OPTIC GYROSCOPE
HERVE C. LEFEVRE and HERVE J. ARDITTY *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 6 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A02/MF A02

This paper reviews the technological evolution of the interferometric fiber gyroscope over the last fifteen years. Today a psychological barrier has been passed, and it is now accepted that this new technology will find many applications during the 90's. Author

N93-13215# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.
A NOVEL-HIGH-PERFORMANCE SYSTEM FOR RECORDING AND ANALYSING INSTANTANEOUS TOTAL PRESSURE DISTORTION IN AIR INTAKES
K. W. LOTTER and R.-D. SCHERBAUM *In* AGARD, Aerodynamic Engine/Airframe Integration for High Performance Aircraft and Missiles 16 p (SEE N93-13199 03-34) Sep. 1992
(AGARD-CP-498) Copyright Avail: CASI HC A03/MF A04

Instantaneous intake total pressure distortion parameters are generally used to assess aerodynamic intake-engine compatibility. Different distortion parameters are applied by the various engine manufacturers. Distortion boundaries are specified which are not to be exceeded in the intake during the whole flight regime. The quantification of those parameters is generally made in intake wind-tunnel model tests. In these tests the instantaneous total pressure is measured in the Aerodynamic Interface Plane (AIP) (a short distance upstream of the engine compressor face) by high-response pressure transducers, typically installed on an eight-arm rake with five probes on each arm. In the past, after having undergone the relevant signal conditioning process, the signals from the transducers were combined to the above-mentioned distortion parameters by the use of an analog computer. Later on, this was supplemented by limited digital analysis of the high-frequency signals. Because of the large amount of data, the digital analysis was only applied over a predetermined short time period. The evolution of high-performance digital data storage facilities combined with highspeed analog-digital conversion now allows a major step forward to longtime digital recording and analysis during intake distortion tests. The novel system that has been installed at MBB and successfully applied during various intake wing-tunnel test campaigns is described. Dynamic signals from up to 144 high-response differential transducers can be recorded. Individual control lines are used for sensing, power supply, and in-situ calibration. A specially configured computer system is used to control the signal frequency band, the number of signal channels, the control lines, and the sample rate. The computer is also used to control the storage of the digitized data on an advanced high density tape recording system that allows continuous recording of up to 1 hour on a cassette tape. The data rate for tape storage is as high as 107 Mbits/s. Parallel to this storage process it is possible to calculate, in an on-line real-time mode, the desired instantaneous distortion parameters using an analog computer. For recording times of up to 5 seconds for each data point, digital on-line analysis is also possible. The data can be displayed on a screen and are also plotted during the test, thus allowing the test engineer to react quickly and alter or adapt the test program. Typical results from tests with different intake models in various wind-tunnel facilities are presented. The effect of digitization rate and recording time on the error of the calculated instantaneous distortion parameters is shown. Author

N93-19927# British Aerospace Defence Ltd., Preston (England).
DEVELOPMENT AND FLIGHT TESTING OF A SURFACE PRESSURE MEASUREMENT INSTALLATION ON THE EAP DEMONSTRATOR AIRCRAFT
G. J. WATSON *In* AGARD, Flight Testing 13 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

This paper describes a project to develop and flight test a surface pressure measurement system on the UK Experimental Aircraft Program demonstrator aircraft. The paper begins with a brief description of the potential benefits of developing such a system. This is followed by the results and conclusions of development tests involving Wind Tunnel measurements and some preliminary Flight Trials. The installation details for the main Flight Test Trials are then described and the final results from the system are presented, compared with predictions based on previous Wind Tunnel measurements. The capability of the system to provide pressure distribution data of interest to the Aerodynamicist and integrated component loads for Flight Clearance purposes is demonstrated, and its usefulness as a Flight Testing technique is discussed. Author

N93-22021# GEC Avionics Ltd., Rochester (England). Guidance Systems Div.
INITIAL TRIALS RESULTS FOR IMAGE STABILISATION USING A RUGGED LOW NOISE GYROSCOPE
D. G. HARRIS *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 7 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A02/MF A02

Several motion sensors of novel design have been developed during the past decade with the guided weapon or projectile market as the target user. In addition to technical performance requirements, all such sensors must be very robust with small size and mass, low power consumption and low cost. START is an angular rate sensor developed for this purpose. However, the guided munitions market has been very slow to evolve and new applications were sought in which the characteristics listed above, plus a very long operating and shelf life could be exploited. The field of image stabilization seemed promising and applications for use were followed up. The paper describes the characteristics of START which make it suited to this field and discusses some of the specific applications and the results achieved in tests of these equipments. Author

N93-22783# Litton Guidance and Control Systems, Woodland Hills, CA.
AN OVERVIEW OF OPTICAL GYROSCOPES FOR NAVIGATION
J. G. MARK and D. A. TAZARTES *In* AGARD, Integrated and Multi-Function Navigation 9 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A02/MF A02

In the 1980's, Ring Laser Gyroscopes (RLG) displaced the mechanical (spinning wheel) gyroscope as the angular sensor of choice for navigation. While the RLG remains the standard navigation grade instrument, several other optical gyroscopes have recently appeared. The multi oscillator (or four-mode gyro) represents a new generation in laser gyroscopes. Systems based on this technology are now being delivered for use on commercial

and military aircraft. Another optical sensor, the fiber optic gyroscope (FOG) has been incorporated in inertial measurement units (IMU) and proved itself capable of AHRS (attitude and heading reference system) accuracy. This gyroscope should find many applications in aided navigation systems. Integrated FOG/GPS systems appear attractive as low cost navigators. This paper addresses technology involved in these optical gyroscopes and discusses their advantages and disadvantages in relation to present and future applications. Author

N93-22784# Delco Electronics, Goleta, CA.
HEMISPHERICAL RESONATOR GYRO: PRINCIPLE, DESIGN, AND PERFORMANCE
W. W. STRIPLING and JOHN R. BASKETT *In* AGARD, Integrated and Multi-Function Navigation 6 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A02/MF A02
The Hemispherical Resonator Gyro (HRG) is a new-technology rotation-sensing instrument based on the precession of a standing wave around a vibrating hemispherical form. This paper presents the principle of the HRG and describes the design and performance of some actual instruments. Author

N93-22785# LITEF, Freiburg (Germany).
FIBER OPTIC GYROS AND SYSTEMS
H.-J. BUESCHELBERGER and E. HANDRICH *In* AGARD, Integrated and Multi-Function Navigation 13 p (SEE N93-22780 08-04) Nov. 1992
(AGARD-CP-525) Copyright Avail: CASI HC A03/MF A02
Fiber Optic Gyroscopes have emerged from the engineering laboratories and come into production. Conventional gyros will be replaced by the fiber optical gyros in most applications in the near future. LITEF has developed a family of gyros and systems based on these gyros. The introduction of the new technology brings many advantages with respect to function, performance, size and weight. Author

N93-22786# Sextant Avionique, Valence (France).
SILICON ACCELEROMETER FOR AHRS AND HYBRID NAVIGATION SYSTEMS [ACCELEROMETRE SILICIUM POUR AHRS ET SYSTEMES HYBRIDES DE NAVIGATION]
J. LECLERC, A. DEFOSSE, and O. LEFORT *In* AGARD, Integrated and Multi-Function Navigation 5 p (SEE N93-22780 08-04) Nov. 1992 In FRENCH
(AGARD-CP-525) Copyright Avail: CASI HC A01/MF A02
The SEXTANT Avionic company possesses a large spectrum of accelerometers for the different applications of Navigation. Since 1980, a constant concern about their adequacy to meet the need has led SEXTANT Avionic to develop micro-machined captors and accelerometers in particular. Many types of materials have been used and we expose the reasons for the choice of silicon in accelerometers destined for AHRS. The architecture of the accelerometer, the technologies used, and the functional modes are described. Then the actual performances of the different types of silicon accelerometers are explained, as well as their domain of application. In conclusion, perspectives of a longer term are given. Author

N93-29942# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. for Propulsion Technology.
AN L2F-MEASUREMENT DEVICE WITH IMAGE ROTATOR PRISM FOR FLOW VELOCITY ANALYSIS IN ROTATING COOLANT CHANNELS
M. BEVERSDORFF, O. HEIN, and R. SCHODL *In* AGARD, Heat Transfer and Cooling in Gas Turbines 7 p (SEE N93-29926 11-07) Feb. 1993
(AGARD-CP-527) Copyright Avail: CASI HC A02/MF A04
For further improvement of the turbine blade cooling process, the knowledge concerning the heat transfer in radial coolant channels has to be deepened. Due to rotation, the velocity distribution, as well as the turbulence structure and therefore the heat transfer, will be influenced. To carry out experimental data of the flow field within a rotating duct a non-intrusive continuous measuring system (Laser-Two-Focus) with an image rotator prism is presented. The design of the system is explained in detail. Problems of application are discussed and results of the first successful measurements compared with numerical results are presented. Author (revised)

N94-10438# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
THERMAL FLUX MEASUREMENTS IN HYPERSONIC FLOWS: A REVIEW
J. F. WENDT, D. BALAGEAS (Office National d'Etudes et de Recherches Aerospatiales, Paris, France.), and R. D. NEUMANN (Dayton Univ. Research Inst., OH.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 5 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A01/MF A04
This contribution reviews the papers presented in the Session on 'Heat Flux' and 'Thermography' at a NATO Advanced Research Workshop entitled 'New Trends in Instrumentation for Hypersonic Research', 27 April-1 May, 1992, Le Fauga, France. The present status and problem areas associated with specific methods are discussed and recommendations for future research and development are presented. Author (revised)

N94-11332# Pennsylvania State Univ., University Park, PA. Materials Research Lab.
RECENT DEVELOPMENTS IN PIEZOELECTRIC AND ELECTROSTRICTIVE SENSORS AND ACTUATORS FOR SMART STRUCTURES
L. ERIC CROSS *In* AGARD, Smart Structures for Aircraft and Spacecraft 33 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04
Piezoelectricity will be defined phenomenologically and discussed pictorially to underscore the distinction between single crystal piezoelectrics and the poled ceramics which form the basis for most practical sensor and actuator systems. The classical lead zirconate: lead titanate (PZT) family is the most widely used. Recent advances in the understanding of the conventional morphotropic phase boundary (MPB) compositions are discussed with particular emphasis upon the nature and the control of fatigue at high strain levels. Phase switching compositions in the lead zirconate stannate titanate PZSnT system exhibit very high switching volume strain, shape memory, and controlled induced piezoelectric response. Electrostrictors in the lead magnesium niobate: lead titanate and lead lanthanum zirconate titanate (PMN:PT and PLZT) families form most interesting spin glass states at lower temperature in which precise reproducible elastic strain may be induced by electric field. In PMN:PT the strain is free from aging and other domain related problems, the thermal expansion is very low, and these materials are ideal for very precise actuation. Polarization biased electrostrictors have exceedingly high induced piezoelectric d(sub 33), d(sub 31), and d(sub h) coefficients and can be used as agile transducers in which both the magnitude and phase of the response is under DC field control. Both spin glass and phase switching systems can be tuned in composition to optimize performance at 100 K and provide low power 'dial-a-displacement' capability. Recent advances in the fabrication of highly perfect thin films of PZT type compositions on silicon, by both vapor and liquid phase techniques provides a new high force electromechanical power source for microelectromechanical (MEMS) systems. The current status of the evaluation of electromechanical response in PZT, PMN:PT and PbSnZT thin films on silicon is briefly reviewed and possible applications in MEMS systems discussed. Author (revised)

N94-11340# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. for Flight Guidance.
FIBER-OPTIC INTERFEROMETRIC STRAIN GAUGE FOR SMART STRUCTURES APPLICATIONS: FIRST FLIGHT TESTS
N. FUERSTENAU, D. D. JANZEN, and W. SCHMIDT *In* AGARD, Smart Structures for Aircraft and Spacecraft 6 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A02/MF A04
Initial flight tests of a fiber-optic strain gauge (OSG) based on a double-polarization Michelson interferometer with incremental readout via fringe counting were performed. The passive quadrature demodulation technique allows for balanced interferometer arms, exhibiting partial self temperature compensation. A bent reference (R) arm approach for the sake of isolation of the R-arm from the strain to be measured was tested for the first time. The sensor was surface adhered on a carbon fiber reinforced plastic plate which, in turn, was screwed to the main wing spar of a Cessna C207A aircraft. Strain was measured under different flight

conditions and compared to the readout of a conventional resistive strain gauge (ESG). Good agreement with the theoretical predictions as well as with the readout of the ESG was observed for short term (of the order of minutes) quasistatic strain measurements despite large vibration induced noise. The Fourier spectra of the time series exhibited also good agreement between ESG and OSG with respect to the dynamical response up to at least 250 Hz. The measurement range and stability of the present experimental setup is limited by polarization instabilities which partly are due to anisotropic transverse stress effects at the adhered fiber sections. Longer term dc strain measurements require carefully controlled isotropic adhesion conditions and miniaturized optomechanical components with improved mechanical stability.
Author

N94-33940# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
BASIC PRINCIPLES OF FLIGHT TEST INSTRUMENTATION ENGINEERING, VOLUME 1, ISSUE 2 [INTRODUCTION GENERALE AUX PRINCIPES DE BASE DE L'INSTRUMENTATION DES ESSAIS EN VOL]
ROBERT W. BOREK, SR., ed. (National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Center, Edwards, CA.) and A. POOL, ed. (National Aerospace Lab., Amsterdam, Netherlands.) Mar. 1994 295 p Flight Test Instrumentation Series
(AD-A282984; AGARD-AG-160-VOL-1-ISSUE-2; ISBN-92-835-0731-2) Copyright Avail: CASI HC A13/MF A03
Volume 1 of the AG 300 series on 'Flight Test Instrumentation' gives a general introduction to the basic principles of flight test instrumentation. The other volumes in the series provide more detailed treatments of selected topics on flight test instrumentation. Volume 1, first published in 1974, has been used extensively as an introduction for instrumentation courses and symposia, as well as being a reference work on the desk of most flight test and instrumentation engineers. It is hoped that this second edition, fully revised, will be used with as much enthusiasm as the first edition. In this edition a flight test system is considered to include both the data collection and data processing systems. In order to obtain an optimal data flow, the overall design of these two subsystems must be carefully matched; the detail development and the operation may have to be done by separate groups of specialists. The main emphasis is on the large automated instrumentation systems used for the initial flight testing of modern military and civil aircraft. This is done because there, many of the problems, which are discussed here, are more critical. It does not imply, however, that smaller systems with manual data processing are no longer used. In general, the systems should be designed to provide the required results at the lowest possible cost. For many tests which require only a few parameters, relatively simple systems are justified, especially if no complex equipment is available to the user. Although many of the aspects discussed in this volume apply to both small and large systems, aspects of the smaller systems are mentioned only when they are of special interest. The volume has been divided into three main parts. Part 1 defines the main starting points for the design of a flight test instrumentation system, as seen from the points of view of the flight test engineer and the instrumentation engineer. In Part 2 the discussion is concentrated on those aspects which apply to each individual measuring channel, and in Part 3 the main emphasis is on the integration of the individual data channels into one data collection system and on those aspects of the data processing which apply to the complete system. Author (revised)

N95-19254# Coimbra Univ. (Portugal). Grupo de Mecanica dos Fluidos.
CALIBRATION AND USE OF A NON-NULLING SEVEN-HOLE PRESSURE PROBE
M. C. G. SILVA and D. X. VIEGAS *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 7 p (SEE N95-19251 05-34) Jul. 1994
(AGARD-CP-535) Copyright Avail: CASI HC A02/MF A04
The calibration and the measuring methods associated with the use of a non-nulling seven-hole pressure probe are exposed. A detailed analysis of the error associated with the fitting process used in the calibration is presented. Some results related with the use of the probe for the determination of average local flow properties (incidence angles and dynamic pressure coefficient) in wind tunnel tests are presented. Author

N95-19255# Institute for Aerospace Research, Ottawa (Ontario).
APPLICATIONS OF THE FIVE-HOLE PROBE TECHNIQUE FOR FLOW FIELD SURVEYS AT THE INSTITUTE FOR AEROSPACE RESEARCH
L. H. OHMAN (De Havilland Aircraft Co. of Canada Ltd., Downsview, Ontario.) and V. D. NGUYEN *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 15 p (SEE N95-19251 05-34) Jul. 1994 Original contains color illustrations
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04
This paper deals with calibrations and uses of the five-hole probes for flow field survey. Two applications are given: one in transonic regime in the near slipstream of a powered propfan mounted on a half-model wing configuration and the other behind a generic submarine model at subsonic speeds. The acquired data have been analyzed in terms of flow angles, total and dynamic pressures and Mach number and velocity vector in a probe fixed coordinate system. These parameters were necessary in determining the flow field characteristics of the studied configurations which are presented and discussed. Author

N95-19256# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
IMPROVEMENT AND VALIDATION OF AN LDV SYSTEM TO PERFORM MEASUREMENTS IN LAMINAR SUPERSONIC FLOWS
LUCA BERTUCCIOLI and GERARD DEGREZ *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 8 p (SEE N95-19251 05-34) Jul. 1994
(Contract(s)/Grant(s): CEC-AERO-0027-C; CEC-ERB-CHBI-CT-92049)
(AGARD-CP-535) Copyright Avail: CASI HC A02/MF A04
This paper describes the optimization and systematic testing of a single component LDV system developed to perform measurements on the tests carried out to validate the performance of the system and on issues which are particular to high speed LDV applications. Particular emphasis is given to issues connected to the seeding of the flow such as the constraints on the selection of a seeding material and its sizing. Oblique shock wave traverses were performed to validate the selected seeding material and the developed seeding delivery system. These tests confirmed the monodispersity of the seeding in the wind tunnel test section and showed a reasonable particle response. The oblique shock traverse results are also compared to various particle dynamics models though the comparison is inconclusive. A series of supersonic laminar boundary layer traverses were also performed. These profiles are compared to the compressible flat plate boundary layer theory of Chapman and Rubesin and the validity of this theory in the current test conditions is demonstrated. The boundary layer measures are in good agreement with the theory, show good repeatability and do not display any signs of particle lag errors. Collectively, these experimental results clearly demonstrate the ability of the LDV system to perform accurate measurements in complex compressible flowfields. Author

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LASERS AND MASERS

Includes parametric amplifiers.

N92-22823# Atmospheric Sciences Lab., White Sands Missile Range, NM.
ANALYSIS ALGORITHMS FOR PROCESSING ULTRAVIOLET FLUORESCENCE DATA
J. B. GILLESPIE, D. L. ROSEN, Y. P. YEE, and R. GONZALES *In* AGARD, Remote Sensing of the Propagation Environment 6 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03
Laser induced fluorescence (LIF) lidar is a promising technique for remote chemical detection and analysis for both hard targets

and extended atmospheric targets dispersed as aerosols or gases. The fluorescence spectra of the hard targets and of the aerosols and gases in the troposphere are primarily very broad and devoid of sharp line structure. When several species are present, the resulting overlapped spectrum is difficult to analyze. Interpretation of the multicomponent spectra of the lidar signal return is necessary for application of an UV lidar in a complex atmospheric environment such as a modern battlefield. Algorithms are described that were developed to process UV lidar fluorescence data and to analyze for chemical components. The analysis algorithms are based on factor analysis rank annihilation (FARA) techniques. Four methods are applied to lidar systems modeling and simulation analysis that contains both shot noise and sky radiance. The limitations are shown of UV lidar systems in terms of range, daytime/nighttime operation, and lidar system parameters. It was found that for situations in which several constituents are fluorescing and have close overlap, sky radiance limits nighttime use. Author

N93-19926# Aerospatiale, Toulouse (France).
USE OF A TRIAXIAL LASER VELOCIMETER FOR ANEMOMETRIC CALIBRATION ON AN A340 AIRBUS [UTILISATION D'UN VELOCIMETRE LASER TRIAXE POUR CALIBRATION ANEMOMETRIQUE SUR AIRBUS A340]
F. CATTIN-VALSECCHI and C. LOPEZ *In* AGARD, Flight Testing 10 p (SEE N93-19901 06-05) Oct. 1992 In FRENCH
(AGARD-CP-519) Copyright Avail: CASI HC A02/MF A04
Calibration of the anemometric and clinometric system is an essential phase of the test campaign in the development of an aircraft. The general operating principle of a laser velocimeter is explained along with the technical specifications and installation of the apparatus, developed by the 'Sextant Avionique' company for Aerospatiale. The advantages offered by the new analysis methods using the laser velocimeter are reviewed. Author

N94-36619# Diehl G.m.b.H. und Co., Roethenbach (Germany). Optoelectronics Div.
POINTING AND TRACKING CONCEPT FOR A HIGH ENERGY LASER WEAPON APPLICATION
M. NOLL and B. WARM *In* AGARD, Pointing and Tracking Systems 10 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02
In order to profit from the advantages of a higher energy laser weapon for air defense tasks against aircraft, helicopters or missiles, a suitable laser source and a high-accuracy tracking and pointing system is required. The following publication describes a possible pointing and tracking concept for a laser weapon in order to compensate for the most important factors of disturbance and solve the problems faced when engaging airborne targets. In addition to describing the influence of the effects occurring during the laser beam propagation through the atmosphere and the methods for its compensation, this article will focus on the concept and the characteristics of the tracking and pointing system and its components, designed for a high energy laser weapon application. Finally, this publication gives a detailed description of the functional link of the essential subsystems and components of the pointing and tracking concept for high energy laser weapon applications. Author

N94-36620# Thomson-TRT Defense, Guyancourt (France).
LASER DESIGNATION PODS OPTIMIZED CONCEPT FOR DAY/NIGHT OPERATIONS [PODS DE DESIGNATION LASER UN CONCEPT OPTIMISE POUR LES OPERATIONS JOUR/NUIT]
YVES HUGUENIN *In* AGARD, Pointing and Tracking Systems 7 p (SEE N94-36616 12-18) May 1994 In FRENCH
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02
The conception of an optimized laser guided weapon that can be used at any time requires some technologies which, today, are not always compatible within the same equipment. From the 'day' ATLIS concept, Thomson-CSF developed a complementary 'night' pod. This convertible laser designation pod is the result of technical and operational optimization. Transl. by FLS

N94-36621# Thermo Electron Technologies Corp., San Diego, CA.
ADAPTIVE OPTICS FOR LASER BEAMFORMING IN THE ATMOSPHERE
M. LEFEBVRE, L. CUELLAR, D. SANDLER, and S. STAHL *In* AGARD, Pointing and Tracking Systems 10 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02
We report on the operational and performance of an integrated 1 meter adaptive optics system for compensation of atmospheric distortion of optical wavefronts. A visible artificial laser guide star (frequency-doybled Nd:YAG laser with wavelength of 0.532 microns) is used as the source for the reference wavefront. A shearing interferometer which uses a narrow optical bandwidth and has 500 subapertures is employed to sense wavefront distortion. These measurements are used to compute a conjugate wavefront to the distorted input light. The computed conjugate is then imprinted on a deformable mirror which consists of 500 square mirror segments. The effectiveness of the compensation is measured two ways: by imaging stars with a high resolution CCD camera in a narrow spectral bandwidth centered at 0.532 microns from which the point spread function is computed, or by collecting illuminator light reflected from a remote object with a photomultiplier tube. Atmospheric experiments are under way to test the performance of the integrated system. The results of these tests are very promising, yielding short-exposure stellar images which contain discernible energy at the diffraction limit of 0.1 arcsec, as well as a noticable improvement in the amount of light reflected from a remote target. Author

N95-19258# Centre d'Etudes et de Recherches, Toulouse (France). Dept. d'Etudes et de Recherches en Aero-Thermodynamique.
EXPERIMENTAL TECHNIQUES FOR MEASURING TRANSONIC FLOW WITH A THREE DIMENSIONAL LASER VELOCIMETRY SYSTEM. APPLICATION TO DETERMINING THE DRAG OF A FUSELAGE [TECHNIQUE EXPERIMENTALE DE MESURE EN ECOULEMENT TRANSSONIQUE AVEC UN SYSTEME DE VELOCIMETRIE LASER TRIDIMENSIONNEL. APPLICATION A LA DETERMINATION DE LA TRAINEE D'UN FUSELAGE]
A. SERAUDIE, A. MIGNOSI, J. B. DOR, and S. PRUDHOMME *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 6 p (SEE N95-19251 05-34) Jul. 1994 In FRENCH Original contains color illustrations
(AGARD-CP-535) Copyright Avail: CASI HC A02/MF A04
Recent developments in laser anemometry have been used to design a three dimensional laser system which has been in operation at the CERT ONERA's T2 wind tunnel since December 1989: fiber optics (to lead the light between the source and the emitting optics), Fast FOURIER Transfer Doppler processors (to analyze the Doppler signals), high power transmission system (to provide color separation), digital control of displacement motors and real time operation (to move the measuring point during the run). This device works well for the short run times of the T2 wind tunnel, providing a good accuracy which allows 30 to 50 measurement points during 60 to 120 seconds of the test. After a complete description of the 3D laser velocimetry system, the present paper will develop some typical measurements which have been performed. For each case we will present some test results obtained under transonic conditions: shock wave probing (shape and location on the upper side of a 2D transonic model); and 3D velocity measurements in forward and backward scatter configurations with the wall approach for areas without good accessibility. In order to obtain the drag of a fuselage, a vertical plane located downstream of the model was measured with two devices: laser velocimetry in order to obtain the three components of velocity; and a pressure rake providing the static and total pressures. The combination of these measurements (pressure and velocity) allowed the calculation of the total drag of the 3D model. Author

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MECHANICAL ENGINEERING

Includes auxiliary systems (nonpower); machine elements and processes; and mechanical equipment.

N94-34466# Sussex Univ., Brighton (England). Thermo-Fluid Mechanics Research Centre.
AN AIR BEARING SYSTEM FOR SMALL HIGH SPEED GAS TURBINES
A. B. TURNER, S. J. DAVIES, and Y. L. NIMIR *In* AGARD, Technology Requirements for Small Gas Turbines 8 p (SEE N94-34431 10-07) Mar. 1994 Sponsored by Rolls-Royce Ltd. and Aisin Seiki Co. Ltd.
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

This paper describes the second phase of an experimental program concerning the application of air bearings to small turbomachinery test rigs and small gas turbines. The first phase examined externally pressurized (EP) journal bearings, with a novel EP thrust bearing, for application to 'warm air' test rigs, and was entirely successful at rotational speeds in excess of 100,000 rpm. This second phase examined several designs of tilting pad-spiring journal bearings, one with a novel form of externally pressurized pad, but all using the original EP thrust bearing. The designs tested are described, including some oscillogram traces, for tests up to a maximum of 70,000 rpm; the most successful using a carbon pad-titanium beam spring arrangement. The thrust bearing which gave trouble-free operation throughout, is also described. The results of an original experiment to measure the 'runway speed' of a radial inflow turbine are also presented, which show that overspeeds of 58 percent above the design speed can result from free-power turbine coupling failure. Author

N94-36627# McDonnell-Douglas Aerospace, Saint Louis, MO.
AEROSERVOELASTIC STABILIZATION CONSIDERATIONS FOR POINTING AND TRACKING SYSTEMS
PETER Y. CHENG and RALPH E. LAMBERT *In* AGARD, Pointing and Tracking Systems 6 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02

The high gain, wide bandwidth precision tracking/pointing systems used on advanced aircraft necessitate the consideration of aeroservoelasticity (ASE) early in the design process. Aircraft control systems are designed to meet stability, performance and, in the case of manned aircraft, handling qualities criteria defined by the Mil-Spec requirements. As digital controllers are introduced, airframes are made statically unstable, and as the push for increased dynamic response continues, the aeroservoelastic influences become increasingly important in the overall system performance. At times, the ASE considerations may dominate the rigid body control law design effort. This paper summarizes an approach to the ASE stabilization of a fighter aircraft when used as the integral part of a high bandwidth manual or automatic fire control tracking system. The same approach can be applied to standard manual control aircraft where a more thorough ASE analysis is desired. Author

N95-14128# Sulzer Innotec A.G., Winterthur (Switzerland). Fluid Dynamics Lab.
COMPUTATIONAL METHODS FOR PRELIMINARY DESIGN AND GEOMETRY DEFINITION IN TURBOMACHINERY
M. V. CASEY *In* AGARD, Turbomachinery Design Using CFD 22 p (SEE N95-14127 03-34) May 1994
(AGARD-LS-195) Copyright Avail: CASI HC A03/MF A03

A review of the turbomachinery preliminary design process is given with particular emphasis on axial and radial compressors. The review covers the selection of machine type, mean-line analysis and correlations, stagestacking calculations and the use of design charts and optimization techniques to find optimum values for design parameters. A comparison is made between the most successful correlations for endwall losses in axial compressors to highlight the different approaches that are possible. The preliminary design process provides an initial definition of the skeletal geometry of the blading and the annulus of the turbomachine. Turbomachinery design systems are then based on design by analysis, whereby the blading is assessed using CFD codes and is iteratively refined. A numerically based parametric blade geometry definition system makes the use of CFD considerably more effective. Examples of modern turbomachinery geometry definition methods involving Bezier surfaces and B-splines are described. Author

N95-14129# General Electric Co., Cincinnati, OH. Aircraft Engines Div.
ELEMENTS OF A MODERN TURBOMACHINERY DESIGN SYSTEM
IAN K. JENNIONS *In* AGARD, Turbomachinery Design Using CFD 22 p (SEE N95-14127 03-34) May 1994
(AGARD-LS-195) Copyright Avail: CASI HC A03/MF A03

The aerodynamic design system at GE Aircraft Engines (GEAE) consists of many parts: throughflow, secondary flow, geometry generators, blade-to-blade and fully three-dimensional (3D) analysis. This paper describes each of these elements and discusses optimization and computer architecture issues. Emphasis is placed on those areas in which the company is thought to have special capability. Author

N95-14130# Cambridge Univ., Cambridge (England). Dept. of Engineering.
DESIGNING IN THREE DIMENSIONS
J. D. DENTON *In* AGARD, Turbomachinery Design Using CFD 14 p (SEE N95-14127 03-34) May 1994
(AGARD-LS-195) Copyright Avail: CASI HC A03/MF A03

This lecture advocates the direct use of three-dimensional flow calculations for turbomachinery design. The limitations of the usual quasi-three dimensional approach are discussed and it is shown that fully 3D calculations overcome the modelling limitations inherent in them. Fully 3D calculations also avoid the need to iterate between throughflow and blade to blade calculations. This leads to fewer routine operations (e.g. data transfers) being needed during the design process and hence more efficient use of the designer's time. With a flexible geometrical package, able to generate blade sections and transfer their geometry directly to a 3D data set, changes of stage geometry can be made in minutes. An outline of such a package is given. Modern 3D calculation methods, Ref(11), enable complete stage solutions. with adequate accuracy for design purposes, to be obtained in the order of I hour on a workstation. Hence several design iterations per day can be easily be performed for a single stage of a machine. An example used to design a very high pressure ratio (3:1) axial fan is given and discussed. Author (revised)

N95-14947# Alcatel Espace, Toulouse (France).
MISSION, TECHNOLOGIES AND DESIGN OF PLANETARY MOBILE VEHICLE
MICHEL HAYARD *In* AGARD, Advanced Guidance and Control Aspects in Robotics 7 p (SEE N95-14942 03-63) Jun. 1994
(AGARD-LS-193) Copyright Avail: CASI HC A02/MF A03

The French Space Agency (CNES) started a study in late 1992 of an autonomous rover VAP (for Planetary Autonomous Vehicle). The aim of this study was to investigate multimission mobile platform design. The focus was placed on a martian mission for several reasons: (1) there is a very high scientific interest for Mars surface exploration leading to a better understanding of the solar system and Earth evolution; (2) roving on the planet is one mandatory and preliminary step before the conquest of the 'red planet' by manned mission; and (3) it is a necessary complement to fixed networks and sample return, in order to get data relevant to very large areas. The overall system concept including launch, cruise, deboost from Mars orbit, Mars atmosphere entry, and landing is not part of the study but is only kept in mind, as these phases of the mission induce several constraints. The main results of the study are given, showing the two possibilities: a large vehicle of 450 kg as the baseline and a smaller vehicle of 250 kg as an option. The various subsystems are described and the choices justified. The expected performances are summarized. Author

N95-14948# Bateman (Peter J.), Camberly (England).
GUIDANCE AND CONTROL FOR UNMANNED GROUND VEHICLES
PETER J. BATEMAN *In* AGARD, Advanced Guidance and Control Aspects in Robotics 33 p (SEE N95-14942 03-63) Jun. 1994
(AGARD-LS-193) Copyright Avail: CASI HC A03/MF A03

Techniques for the guidance, control, and navigation of unmanned ground vehicles are described in terms of the communication bandwidth requirements for driving and control of a vehicle remote from the human operator. Modes of operation are conveniently classified as conventional teleoperation, supervisory control, and fully autonomous control. The fundamental problem of maintaining a robust non-line-of-sight communications link between the human controller and the remote vehicle is discussed, as this provides the impetus for greater autonomy in the control system and the greatest scope for innovation. While supervisory control still requires the man to be providing the primary navigational intelligence, fully autonomous operation requires that mission navigation is provided solely by on-board machine intelligence. Methods directed at achieving this performance are described using various active and passive sensing of the terrain for route navigation and obstacle detection. Emphasis is given to TV imagery and signal processing techniques for image understanding. Reference is made to the limitations of current microprocessor technology and suitable computer architectures. Some of the more recent control techniques involve the use of neural networks, fuzzy logic, and data fusion and these are discussed in the context of road following and cross country navigation. Examples of autonomous vehicle testbeds operated at various laboratories around the world are given. Author

N95-19667# National Technical Univ., Athens (Greece). Thermal Engineering Section.
INVESTIGATION OF MECHANICAL EROSION IN FUEL PIPELINES
M. FOUNTI and A. KLIPFEL *In* AGARD, Erosion, Corrosion and Foreign Object Damage Effects in Gas Turbines 7 p (SEE N95-19653 05-07) Nov. 1994
(AGARD-CP-558) Copyright Avail: CASI HC A02/MF A03

The aim of this work is to investigate the characteristics of mechanical erosion in a vertical sudden expansion turbulent two-phase flow. The flow field in an axisymmetric sudden expansion flow laden with round glass particles at 3 percent per volume and flowing in the direction of gravity was examined both experimentally and computationally. Velocities of particles and fluid were simultaneously measured at Re = 6 x 10(exp 4) using a single component laser Doppler anemometer and a burst peak detector which discriminates the amplitude of the Doppler bursts resulting from the two discrete phases. The test facility was refractive index matched, allowing measurement of the bar-U, V, sq bar-u, sq v and sq w components throughout the whole velocity flow field. Computations were performed using a Eulerian/Langrangian approach considering drag, lift and gravity forces acting on a particle as well as modelling of particle-dispersion by turbulence, particle-wall and particle-particle collisions. Mechanical erosion of the pipe wall was determined via an empirical formula, using the predicted impact velocities and angles. Author

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QUALITY ASSURANCE AND RELIABILITY

Includes product sampling procedures and techniques; and quality control.

N93-21528# Brussels Univ. (Belgium). Composite Systems and Adhesion Research Group.
DEFECT ANALYSIS USING ADVANCED INTERPRETATION OF THE REFLECTED WAVE DURING ULTRASONIC SCANNING
L. SCHILLEMANS, D. VANHEMELRIJCK, F. DEROEY, W. P. DEWILDE, A. H. CARDON, and A. A. ANASTASSOPOULOS *In* AGARD, Debonding/Delamination of Composites 17 p (SEE N93-21507 07-24) Dec. 1992 Sponsored by Belgian National Foundation for Scientific Research Prepared in cooperation with Patras Univ., Greece
(AGARD-CP-530) Copyright Avail: CASI HC A03/MF A03

The paper reports recent developments in the field of the interpretation of the form of the reflected wave during ultrasonic scanning of laminated plates. Defect analysis in laminated plates can be achieved by installing a threshold value on the amplitude of the reflected ultrasonic wave. If this threshold value has not been achieved, one considers that a defect is causing scatter and the location is registered as such. This is the most elementary form of measuring technique, although it does not provide more detailed information about the depth location of the defect. Nevertheless, it already provides some information, although rather 'binary'. On the used USIP 12 equipment (Krautkramer) a depth-measurement module was added allowing to establish the location of wave scatter through the thickness of the laminated structure. Recently, it has been suggested that the form of the reflected wave could yield some additional information on the types of defects. In particular, the frequency content of the reflected wave could be analyzed and be compared for different sorts of defects, thus allowing for a more accurate diagnostic of the defect and its significance. Advanced signal processing and pattern recognition techniques are therefore applied. Two Carbon/Epoxy laminated plates with several embedded defects have been manufactured and tested. Representative results will be given. Author

N93-21529# Hellenic Aerospace Industry, Schimatari (Greece). Advanced Materials, Processes and Manufacturing Lab.
DAMAGE DETECTION BY ACOUSTO-ULTRASONIC LOCATION (AUL)
Z. P. MARIOLI-RIGA, A. N. KARANIKA, T. P. PHILIPPIDIS (Patras Univ., Greece.), and S. A. PAIPETIS (Patras Univ., Greece.) *In* AGARD, Debonding/Delamination of Composites 3 p (SEE N93-21507 07-24) Dec. 1992
(AGARD-CP-530) Copyright Avail: CASI HC A01/MF A03

Damage detection in aircraft structures in-situ is important, especially with not visible defects in composite components for a variety of reasons. In the present paper a new technique based on the Acousto-Ultrasonic (AU) concept is introduced, but instead of extracting information from the externally generated pulsed wave, as with AU, the characteristics of waves reflected from defects are measured. In this way it was possible to identify and locate defected areas in honeycomb panels and thermoplastic carbon fiber laminates. The results were correlated with ultrasonic C-scans, and satisfactory agreement was obtained. The present is part of a major project aiming at the development of a fast inspection method for aircraft components during routine maintenance cycles. Author

N94-11335# Manchester Univ. (England). Dynamics Research Group.
FAULT LOCATION IN STRUCTURES USING NEURAL NETWORKS
K. WORDEN, A. D. BALL, and G. R. TOMLINSON *In* AGARD, Smart Structures for Aircraft and Spacecraft 19 p (SEE N94-11317 01-24) Apr. 1993 Sponsored in part by BRITE/EURAM
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

A neural network is trained to report the position of a fault in a framework structure. It is shown that a network trained on data

from finite element simulation of the structure can successfully locate faults in the framework itself. Author (revised)

N94-37321# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

IMPACT OF MATERIALS DEFECTS ON ENGINE STRUCTURES INTEGRITY [L'IMPACT DES DEFAUTS DES MATERIAUX SUR L'INTEGRITE DES STRUCTURES DES MOTEURS]

Apr. 1993 118 p In ENGLISH and FRENCH The 74th meeting was held in Patras, Greece, 27-28 May 1992
(AD-A267718; AGARD-R-790; ISBN-92-835-0711-8) Copyright Avail: CASI HC A06/MF A02

Engine failures due to materials defects are rare, but are still a cause for concern to both manufacturers and lifting authorities. In these circumstances it is recognized that the introduction of higher strength materials, new production routes and improved non-destructive evaluation methods may have significant implications for engine lifing and safety. The impact of inherent defects on present and future component manufacture and on aircraft engine operation is considered. Materials processing and control aspects are reviewed, placing particular emphasis on nickel and titanium engine disc materials. Variations in engineers', scientists' and lawyers' interpretation of the work 'defect' was perhaps the most significant point to emerge from the meeting; so much so, that a small group agreed to develop a definition, and when established recommend it as standard AGARD materials technology. For individual titles, see N94-37322 through N94-37331.

N94-37322# Utah Univ., Salt Lake City, UT. Dept. of Mechanical Engineering.

HISTORY AND PROGNOSIS OF MATERIAL DISCONTINUITY EFFECTS ON ENGINE COMPONENTS STRUCTURAL INTEGRITY

DAVID W. HOEPPNER *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 8 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright Avail: CASI HC A02/MF A02

Ever since the development of aeroengines, 'defects' have been of significant concern to the assurance of structural integrity. Many of these issues have been the focus of recent Structures and Materials Panel (SMP) workshops and conferences. Although engine idealizations of materials being homogeneous, continuous, and 'free of defects' are invoked to make the complex issues of load, stress and strain, tractable, they were recognized as early as 1916, and later in the 1930's, as being oversimplistic and potentially in error. The epistemology of the role of discontinuities ('defects') in the design, selection, and lifing of critical aeroengine components is reviewed herein. Utilization of 'defect-free' and 'initiation' based fatigue criteria (as well as other time dependent failure modes such as creep, wear, etc.) have led to much success in the aeroengine industry. However, 'defects' also have led to numerous engine component failures in military and civilian aeroengines. And, as increasing demands are made on materials used in aeroengines, the role of 'defects' will, undoubtedly, become more important and critical. The history and prognosis of these issues is discussed with a review of on-condition lifing, defect-tolerant and damage-tolerant approaches, including, but not limited to, Engine Structural Integrity Program (ENSIP). The prognosis will suggest the need for the following: (1) development of increased understanding of the physics of failure processes of aeroengine materials; (2) integration of 'defect' considerations in the lifing methodologies from conceptual to detail design (the new paradigm of lifing); (3) assurance that knowledge of intrinsic materials behavior, including manufacturing specification and control, is a prime consideration in the defect-tolerant approach; (4) non-destructive inspection and evaluation should be one of many tools used to monitor and assure the state of the materials and should be a consideration in the lifing methodology at the earliest stage; (5) evaluation and integration of the role of extraneous influences, such as fretting, environmental attack, and the like, and how they are factored into the lifing procedure; and (6) development of consistent terminology with standardized definitions. Author

N94-37329# Fiat Aviazione S.p.A., Turin (Italy).

TURBINE DISKS: LIFING AGAINST DEFECTS AND MATERIALS DEVELOPMENT

E. CAMPO, G. PASQUERO, ALDO FREDIANI, and ROBERTO GALATOLO *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 12 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright Avail: CASI HC A03/MF A02

Structural integrity of turbine disks must be guaranteed with a high safety level. The Engine Structural Integrity Program as contained in NIL-STD-1783 is aimed to enhance disk safety. A major design requirement is the implementation of the Damage Tolerance concepts by assessing the disk life in presence of defects. This paper illustrates the MIL-STD-1893 impact on turbine design as well as on material requirements, putting more emphasis on induced discontinuity features than on evolutionary ones. Targets for future developments in lifing procedures as well as in innovative materials are defined. taking into account possible differences in life management among NATO countries. Author

N94-37330# General Electric Co., Cincinnati, OH. Aircraft Engines.

SUBSTANTIATING POWDER METAL LIFE METHODOLOGIES FOR ENGINES

P. A. DOMAS *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 8 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright. Avail: CASI HC A02/MF A02

The application of powder metal (PM) superalloys in aircraft turbine engine rotating components is prompted by performance driven high strength and creep resistance requirements. Fine grain, precipitation strengthened nickel-base alloys such as IN100, Rene'95, and Rene'88DT meet these requirements up to operating temperatures in the 1200-1300F (649-704C) range. In addition to burst and deformation limits, design constraints include durability (fatigue) and damage tolerance (crack growth resistance) capability to insure reliability and safety. Fatigue life for these alloys can be influenced by inhomogeneities (inclusions) intrinsic to the microstructure as the result of processing, and by perturbations of the surface integrity during component manufacture and subsequent usage. Understanding of PM fatigue behavior and substantiation of life assessment methodology must appropriately recognize these potential influences. New testing, modeling, and analysis schemes are necessitated in engineering development programs addressing generation and validation of life prediction techniques for these materials. This paper outlines one approach to substantiating PM fatigue life prediction that attempts to recognize homogeneous fatigue initiation by incorporating probabilistic models and development testing methods that address material volume and component feature effects. Complications and limitations being addressed in ongoing work are discussed. Author

N94-37331# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).

PREDICTING DEFECT BEHAVIOUR

G. W. KOENIG and J. W. BERGMANN *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 11 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright Avail: CASI HC A03/MF A02

Fatigue is a statistical phenomenon with contributing factors which are statistical in nature too. Therefore probabilistic lifing concepts appear to be appropriate. Major components of any probabilistic lifting concept are: (1) microstructural characterization; (2) load history; and (3) material behavior. The results of any lifing model can only be as significant as the input data. This paper reviews some important aspects regarding input data which are necessary for the prediction of defect behavior by probabilistic models. Author

N95-20637# Rome Lab., Griffiss AFB, NY.

IMPROVING MULTICHIP MODULE (MCM) DESIGN AND RELIABILITY USING THE INTELLIGENT MCM ANALYZER

MARK J. STOKLOSA, DOUGLAS J. HOLZHAUER, DALE W. RICHARDS, PETER J. ROCCI, and PAUL S. YAWORSKY *In* AGARD, Advanced Packaging Concepts for Digital Avionics 6 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

The Intelligent MCM Analyzer (IMCMA) is a software tool which allows the designer to concurrently assess the reliability of

an MCM design based on operational parameters. Traditionally, this type of assessment takes days to accomplish and is performed after the design phase. The Intelligent MCM Analyzer does not require the designer to be a thermal/reliability expert and gives an assessment in minutes depending on the complexity of the design and the speed of the computer. IMCMA assists the designer in achieving a robust design which will improve both quality and reliability. The software uses object-oriented data representation, a blackboard architecture and heuristic expertise to perform lower level reasoning associated with finite element thermal analysis techniques that are normally very tedious and labor intensive. A test case will be presented comparing results from IMCMA with the results from a general purpose finite element code. The ultimate payoff will be the manufacturers' ability to build higher quality, higher reliability MCM's at a lower cost. Author

N95-20638# Texas Instruments, Inc., Dallas, TX. Defense Systems and Electronics Group.
ULTRA-RELIABLE DIGITAL AVIONICS (URDA) PROCESSOR
REAGAN BRANSTETTER, WILLIAM RUSZCZYK, and FRANK MIVILLE *In* AGARD, Advanced Packaging Concepts for Digital Avionics 10 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

Texas Instruments Incorporated (TI) developed the URDA processor design under contract with the U.S. Air Force Wright Laboratory and the U.S. Army Night Vision and Electro-Sensors Directorate. TI's approach couples advanced packaging solutions with advanced integrated circuit (IC) technology to provide a high-performance (200 MIPS/800 MFLOPS) modular avionics processor module for a wide range of avionics applications. TI's processor design integrates two Ada-programmable, URDA basic processor modules (BPM's) with a JIAWG-compatible PiBus and TMBus on a single F-22 common integrated processor-compatible form-factor SEM-E avionics card. A separate, high-speed (25-MWord/second 32-bit word) input/output bus is provided for sensor data. Each BPM provides a peak throughput of 100 MIPS scalar concurrent with 400-MFLOPS vector processing in a removable multichip module (MCM) mounted to a liquid-flowthrough (LFT) core and interfacing to a processor interface module printed wiring board (PWB). Commercial RISC technology coupled with TI's advanced bipolar complementary metal oxide semiconductor (BiCMOS) application specific integrated circuit (ASIC) and silicon-on-silicon packaging technologies are used to achieve the high performance in a miniaturized package. A Mips R4000-family reduced instruction set computer (RISC) processor and a TI 100-MHz BiCMOS vector coprocessor (VCP) ASIC provide, respectively, the 100 MIPS of a scalar processor throughput and 400 MFLOPS of vector processing throughput for each BPM. The TI Aladdim ASIC chipset was developed on the TI Aladdin Program under contract with the U.S. Army Communications and Electronics Command and was sponsored by the Advanced Research Projects Agency with technical direction from the U.S. Army Night Vision and Electro-Sensors Directorate. Author

N95-20643# Rome Lab., Griffiss AFB, NY.
RELIABILITY ASSESSMENT OF MULTICHIP MODULE TECHNOLOGIES VIA THE TRISERVICE/NASA RELTECH PROGRAM
DANIEL F. FAYETTE *In* AGARD, Advanced Packaging Concepts for Digital Avionics 9 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

Multichip Module (MCM) packaging/interconnect technologies have seen increased emphasis from both the commercial and military communities as a means of increasing capability and performance while providing a vehicle for reducing cost, power and weight of the end item electronic application. This is accomplished through three basic Multichip module technologies, MCM-L that are laminates, MCM-C that are ceramic type substrates and MCM-D that are deposited substrates (e.g., polymer dielectric with thin film metals). Three types of interconnect structures are also used with these substrates and include, wire bond, Tape Automated Bonds (TAB) and flip chip ball bonds. Application, cost, producibility and reliability are the drivers that will determine which MCM technology will best fit a respective need or requirement. With all the benefits and technologies cited, it would be expected that the use of, or the planned use of, MCM's would be more extensive in both military and commercial applications. However, two significant roadblocks exist to implementation of these new technologies: the absence of reliability data and a single national standard for the procurement of reliable/quality MCM's. To address the preceding issues, the Reliability Technology to Achieve Insertion of Advanced Packaging (RELTECH) program has been established. This program, which began in May 1992, has endeavored to evaluate a cross section of MCM technologies covering all classes of MCM's previously cited. NASA and the Tri-Services (Air Force Rome Laboratory, Naval Surface Warfare Center, Crane IN and Army Research Laboratory) have teamed together with sponsorship from ARPA to evaluate the performance, reliability and producibility of MCM's for both military and commercial usage. This is done in close cooperation with our industry partners whose support is critical to the goals of the program. Several tasks are being performed by the RELTECH program and data from this effort, in conjunction with information from our industry partners as well as discussions with industry organizations (IPC, EIA, ISHM, etc.) are being used to develop the qualification and screening requirements for MCM's. Specific tasks being performed by the RELTECH program include technical assessments, product evaluations, reliability modeling, environmental testing, and failure analysis. This paper will describe the various tasks associated with the RELTECH program, status, progress and a description of the national dual use specification being developed for MCM technologies. Author

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STRUCTURAL MECHANICS

Includes structural element design and weight analysis; fatigue; and thermal stress.

N93-31748# Centre d'Essais Aeronautique Toulouse (France).
CRACK GROWTH PREDICTION RESULTS
ERIC JANY, OLIVIER RENNE, and PAUL HEULER (Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn, Germany.) *In* AGARD, AGARD Engine Disc Cooperative Test Programme 83 p (SEE N93-31741 12-07) Apr. 1993
(AGARD-R-766-ADD) Copyright Avail: CASI HC A05/MF A03

Prediction results for the 60 test cases described previously are presented and discussed. The predictions were made by CEAT, NASA, FFA, NLR, and RR (who carried out only a limited number of cases) using the respective models. This chapter starts with a short consideration of criteria for the assessment of model predictions, presents an overview of the whole body of results followed by a discussion of aspects relevant to modeling of crack growth and application within the design process.
Author (revised)

N93-31749# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany).
CONCLUSIONS AND RECOMMENDATIONS
PAUL HEULER, WALTER SCHUETZ, and ERIC JANY (Centre d'Essais Aeronautique Toulouse, France.) *In* AGARD, AGARD Engine Disc Cooperative Test Programme 5 p (SEE N93-31741 12-07) Apr. 1993
(AGARD-R-766-ADD) Copyright Avail: CASI HC A01/MF A03

Preceding chapters have presented and discussed the objectives related to this large collaborative effort as well as relevant test techniques, modeling details and results in great detail. In 1988 an AGARD report had been published on the results obtained within the Core Program which represents the first of two parts of the AGARD Engine Disc Cooperative Test Program. The major issues treated within the present Supplemental Program were: to expand the initial Ti-6Al-4V data base to other titanium materials such as the Beta-processed IMI 685 and Ti-17 (again load controlled LCF tests were carried out on smooth and notched specimens as well as crack growth tests on compact tension (CT) and corner crack (CC) specimens under constant amplitude loading); to consider variable amplitude and spectrum load sequences that would be typical of compressor disc loading conditions; and to apply and evaluate fatigue crack growth modeling techniques based on the material/load cases of the Cooperative Test Program as mentioned above. Additionally microstructural and fractographic analyses were undertaken in order to relate macro crack growth behavior to microstructural features and intrinsic

material properties. In this final chapter, some main aspects and results are summarized. Conclusions and recommendations for future work are given. Author (revised)

N94-11339# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Munich (Germany). Inst. of Aeroelasticity.
STRUCTURAL ANALYSIS AND OPTIMIZATION OF ADAPTIVE STRUCTURES BY USE OF THE FINITE ELEMENT METHOD
R. LAMMERING *In* AGARD, Smart Structures for Aircraft and Spacecraft 11 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A03/MF A04

New finite elements which allow for the analysis and optimization of adaptive structures are presented. Two finite elements accounting for integrated piezo-electric devices are formulated: a shell element for the analysis of shallow shell structures with piezo-electric polymers bonded to the surfaces and a truss element with an integrated piezo-electric ceramic. Test cases are presented to illustrate the potential of the finite elements. The shell element is used to compute the vibration excitation of a thin plate as well as the vibration control of a cantilever beam. The truss element is applied to the problem of optimal actuator placement in adaptive truss structures. For the solution of this problem, objective functions for the minimization of the control effort and the spillover energy are formulated. The second part is concerned with the finite element analysis of the behavior of shape memory alloys. A non-linear one-dimensional finite truss element and a non-linear beam element are used for the analysis of a composite beam with embedded shape memory alloy wires, of which the temperature is varied in order to tune the eigenfrequencies. Author (revised)

N94-34463# Turbomeca S.A. - Brevets Szydlowski, Bordes (France).
VIBRATIONS OF STRUCTURES WITH CYCLIC SYMMETRY: APPLICATION TO THE CASE OF TURBINE ENGINES [VIBRATIONS DE STRUCTURES A SYMETRIE CYCLIQUE: APPLICATION AU CAS DES TURBOMACHINES]
LUDOVIC MEZIERE *In* AGARD, Technology Requirements for Small Gas Turbines 9 p (SEE N94-34431 10-07) Mar. 1994 In FRENCH
(AGARD-CP-537) Copyright Avail: CASI HC A02/MF A04

A great number of gas turbine components gives cyclic symmetry properties which may be useful to analyze such parts. The resonance occurrences are numerous because of the different harmonics of the rotational speed. Shift phase characteristics between each periodic sector can be easily used to represent the complex system forces made of air flow distortions for instance. The aerodynamical forces are transmitted to the structure mainly by the blades. From this point, we note under some stationary pressure deviations, fixed in the space reference, that the airfoil undergoes pressure fluctuations during its revolution cycle. This stationary phenomena is periodic in the blade reference. It shows a forward or backward wave propagation whose frequency is determined within each frame. A couple of eigen modes, except under some particular conditions, can be found using cyclic symmetry conditions at exactly the same eigen value. The linear combination of both modes are used to analyze the wave propagation. Resonance conditions are shown in this paper and an assessment of an excitability factor has been introduced to reckon the potentially dangerous modes. This method is applied on a modal analysis of an impeller of a gas turbine engine designed by TURBOMECA. This step is pre-requisite to a complete simulation of dynamic responses incorporating dissipative functions and the aeroelastic coupling which mainly governs such a vibration phenomena. Author

N94-34464# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec). Static Structure Dept.
ENGINE STATIC STRUCTURES BEHAVIOUR UNDER IMPACT LOAD USING 3D MODELLING
T. LUCAS and K. S. VAN *In* AGARD, Technology Requirements for Small Gas Turbines 22 p (SEE N94-34431 10-07) Mar. 1994 Original contains color illustrations
(AGARD-CP-537) Copyright Avail: CASI HC A03/MF A04

The 3-D finite element method is used to simulate the structural effects of turbine blade impact on gas turbine engine structural casings and flanges, including both local effects and load transfer to the mounts. The analysis uses United Technologies' code WHAM to determine dynamic impact loads, and commercial codes MARC or MSC/NASTRAN to obtain transient stresses and distortions in the casings. The analysis is compared qualitatively and quantitatively to engine test results. Good correlation is obtained in predicting the observed failure. Author

N94-34581# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AN ASSESSMENT OF FATIGUE DAMAGE AND CRACK GROWTH PREDICTION TECHNIQUES [L'EVALUATION DE L'ENDOMMAGEMENT EN FATIGUE ET LES TECHNIQUES DE PREDICTION DE LA PROPAGATION DES FISSURES]
Mar. 1994 278 p 77th Meeting held in Bordeaux, France, 29-30 Sep. 1993
(AD-280273; AGARD-R-797; ISBN-92-835-0734-7) Copyright Avail: CASI HC A13/MF A03

Fatigue is an important consideration in structural design and monitoring of continued airworthiness of military aircraft. This Workshop titled 'An Assessment of Fatigue Damage and Crack Growth Prediction Techniques' provided a forum for an in-depth discussion of the correlation between in-service experience and results from analytical predictive models, specimen level tests, component tests, and full-scale tests. Additionally, it made possible an examination of the operating standards that different countries adopt with respect to various elements in the design process for assessment of fatigue damage. For individual titles, see N94-34582 through N94-34599.

N94-34582# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany).
MINER'S RULE REVISITED
W. SCHUETZ and P. HEULER *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 10 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A02/MF A03

In the first sections, the requirements to be met by hypotheses for fatigue life prediction (including those for the crack initiation and crack propagation phases) are discussed in detail. These requirements are shown to be different for 'scientific' and for 'industrial' fatigue life prediction. Aspects with regard to an assessment of fatigue life prediction hypotheses are discussed. The last section presents the results of a large cooperative program between IABG and several automobile manufacturers, in which Miner's Rule in several versions was assessed against spectrum tests with five different actual automobile components: forged steel stub axle; forged steel stub axle, induction hardened; sheet steel welded rear axle (front wheel drive car); cast aluminum wheel; and welded sheet steel wheel. Since up to 80 components each were available, and two different, but typical, automotive stress-time histories were employed, the assessment was very thorough, avoiding many of the drawbacks of previous assessments. It is shown that damage sums to failure were usually far below 1.0; they also depended on the component in question, the aluminum wheel resulting in the lowest damage sums to failure; the damage sums to failure where always lower for a mild spectrum than for a severe one; and the influence of spectrum variation was predicted best - among the hypotheses tested - by use of a recent proposal of Zenner and Liu. Author (revised)

N94-34583*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FATIGUE LIFE AND CRACK GROWTH PREDICTION METHODOLOGY
J. C. NEWMAN, JR., E. P. PHILLIPS, and RICHARD A. EVERETT, JR. *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 13 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

This paper reviews the capabilities of a plasticity-induced crack-closure model and life-prediction code to predict fatigue crack growth and fatigue lives of metallic materials. Crack-tip constraint factors, to account for three-dimensional effects, were selected to correlate large-crack growth rate data as a function of the effective stress-intensity factor range (Delta K(sub eff)) under constant amplitude loading. Some modifications to the Delta K(sub eff)-rate relations were needed in the near threshold regime to fit small-crackgrowth rate behavior and endurance limits. The model

was then used to calculate small- and large-crack growth rates, and in some cases total fatigue lives, for several aluminum and titanium alloys under constant-amplitude, variable-amplitude, and spectrum loading. Fatigue lives were calculated using the crack-growth relations and microstructural features like those that initiated cracks. Results from the tests and analyses agreed well.
Author (revised)

N94-34584# National Research Council of Canada, Ottawa (Ontario). Structures and Materials Lab.
CRACK GROWTH PREDICTIONS USING A CRACK CLOSURE MODEL
R. L. HEWITT and P. G. COLLINS *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 23 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

Crack growth predictions for through and corner cracks in 7075-T651 plate under constant amplitude loading and corner cracks under two variable amplitude spectra were made using a 'black box' crack closure program. The results were then compared with experiment and various parameters adjusted to give the best match to the experimental results. The optimum parameters chosen will be used for subsequent blind predictions to be made on this material and different but related spectra. Author (revised)

N94-34585# National Aerospace Lab., Amsterdam (Netherlands).
THE CRACK SEVERITY INDEX OF MONITORED LOAD SPECTRA
J. B. DEJONGE *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 5 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A01/MF A03

To assess the consequences with regard to fatigue and damage tolerance of changes in operational usage, a simple means to quantify the relative severity of recorded load spectra is required. This paper describes the development and validation of the 'Crack Severity Index' CSI as a means to express the relative damage in terms of a 'crack growth potential' of stress spectra. The CSI is based on a crack-closure crack growth model and takes account of interaction effects by considering the shape of the spectrum. It is shown that the CSI-concept is a reasonably accurate method to compare the relative severity of maneuver dominated spectra in aluminum alloy structure. Author (revised)

N94-34586# Pisa Univ. (Italy). Dept. of Aerospace Engineering.
AN ASSESSMENT OF FATIGUE CRACK GROWTH PREDICTION MODELS FOR AEROSPACE STRUCTURES
A. SALVETTI, L. LAZZERI, and A. PIERACCI *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 17 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

The current state of crack growth prediction models for aerospace applications is reviewed with special reference to limitations and possible improvements. The present work aims at examining the different crack growth prediction models with reference to effective application for practical use (i.e. with the objective of identifying the experimental data necessary to apply the model) and at quantifying the reliability of the different models. Both crack growth prediction models currently used by aerospace industries and prediction methods under development within the scientific community are considered. An experimental program has been carried out to help achieve the objectives. Author (revised)

N94-34587# McDonnell-Douglas Corp., Saint Louis, MO.
A COMBINED APPROACH TO BUFFET RESPONSE ANALYSES AND FATIGUE LIFE PREDICTION
J. H. JACOBS and R. PEREZ *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 11 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

Experimental measurement and neural network based prediction of wind tunnel model empennage random pressures are discussed. Artificially generated neural network power spectral densities of surface pressures are used to augment existing data and then load an elastic finite element model to obtain response spectra. Details on the use of actual response spectra from flight test data are also discussed. A random spectra fatigue method is described which effectively combines buffet and maneuver loads into a time series based on aircraft usage data. A peak-valley damage analysis procedure is employed to compute the aggregate fatigue life of the structure based on five combined load time series information. Applications of the method as a continual learning tool for buffet response spectra is elaborated.
Author (revised)

N94-34588# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft Div.
NOTCH FATIGUE ASSESSMENT OF AIRCRAFT COMPONENTS USING A FRACTURE MECHANICS BASED PARAMETER
CHR. BOLLER, M. BUDERATH, P. HEULER, and M. VORMWALD *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 16 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

Fatigue life evaluation has been performed for flight-by-flight loaded coupons and real aircraft structural components made of 7075-T7351 using the local strain approach and a fracture mechanics based parameter. Results show that this approach can well compete with the traditionally used nominal stress approach. The advantages are a better understanding of material's fatigue behavior and a less experimental effort required for the determination of baseline data making the local strain approach interesting also for redesign within aircraft mid-life improvement updates. Author

N94-34589# National Aerospace Lab., Bangalore (India).
GROWTH OF ARTIFICIALLY AND NATURALLY INITIATING NOTCH ROOT CRACKS UNDER FALSTAFF SPECTRUM LOADING
R. SUNDER, R. V. PRAKASH, and E. I. MITCHENKO *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 12 p (SEE N94-34581 10-39) Mar. 1994
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

The paper describes an experimental study of notch root fatigue crack growth under FALSTAFF spectrum loading in an Al-Cu alloy. Crack growth rates were measured from crack size as small as 20 microns using optical fractography and replication technique. Fractographic measurements indicate similar scatter levels between notch root short crack and long growth rate data. This is in contrast to surface replica based measurements which are indicative of large scatter. Growth rate variation was noticed between multiple cracks initiating after different periods of natural crack formation. This is attributed to the influence of larger existing cracks on smaller cracks that appear later. In contrast identical artificially initiating cracks grew at a similar rate. Author

N94-34590*# Army Vehicle Structures Lab., Hampton, VA.
ROTORCRAFT FATIGUE LIFE-PREDICTION: PAST, PRESENT, AND FUTURE
RICHARD A. EVERETT, JR. and W. ELBER *In* AGARD, An Assessment of Fatigue Damage and Crack Growth Prediction Techniques 31 p (SEE N94-34581 10-39) Mar. 1994 Sponsored by NASA. Langley
(AGARD-R-797) Copyright Avail: CASI HC A03/MF A03

In this paper the methods used for calculating the fatigue life of metallic dynamic components in rotorcraft is reviewed. In the past, rotorcraft fatigue design has combined constant amplitude tests of full-scale parts with flight loads and usage data in a conservative manner to provide 'safe life' component replacement times. This is in contrast to other industries, such as the automobile industry, where spectrum loading in fatigue testing is a part of the design procedure. Traditionally, the linear cumulative damage rule has been used in a deterministic manner using a conservative value for fatigue strength based on a one in a thousand probability of failure. Conservatism on load and usage are also often employed. This procedure will be discussed along with the current U.S. Army fatigue life specification for new rotorcraft which is the so-called 'six nines' reliability requirement. In order to achieve the six nines reliability requirement the exploration and adoption of new approaches in design and fleet management may also be necessary if this requirement is to be met with a minimum impact on structural weight. To this end a fracture mechanics approach to fatigue life design may be required in order to provide a more accurate estimate of damage progression. Also reviewed in this paper is a fracture

mechanics approach for calculating total fatigue life which is based on a crack-closure small crack considerations. Author

N95-14198# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

HIGH TEMPERATURE CYCLIC BEHAVIOUR OF AEROSPACE MATERIALS: ROOM TEMPERATURE VALIDATION TESTS OF TI-6AL-4V [LE COMPORTEMENT CYCLIQUE HAUTE TEMPERATURE DES MATERIAUX AEROSPATIAUX: LES ESSAIS DE VALIDATION DU TI-6AL-4V]

C. WILKINSON (Defence Research Agency, Farnborough, Hampshire, England.) and C. R. GOSTELOW (Defence Research Agency, Farnborough, Hampshire, England.) Jun. 1994 37 p (AGARD-AR-328; ISBN-92-835-0716-9) Copyright Avail: CASI HC A03/MF A01

Materials specification and distribution of Ti-6Al-4V specimens are presented along with the collated data from those participants that have supplied test results. Crack propagation and strain control low cycle fatigue data are discussed, along with a number of points of clarification regarding test technique. This report, sponsored by the Structures and Materials Panel of AGARD, contains all relevant information on the validation exercise conducted by participants of Working Group 26. Author

N95-19161# Wright Lab., Wright-Patterson AFB, OH. Acoustics and Sonic Fatigue Section.

THERMO-ACOUSTIC FATIGUE DESIGN FOR HYPERSONIC VEHICLE SKIN PANELS

KENNETH R. WENTZ, ROBERT D. BLEVINS (Rohr Industries, Inc., Chula Vista, CA.), and IAN HOLEHOUSE (Rohr Industries, Inc., Chula Vista, CA.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 9 p (SEE N95-19142 05-71) Sep. 1994 (AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

Thermo-vibro-acoustic analysis and test of skin panels for airbreathing hypersonic vehicles is made for a generic vehicle and trajectory. Aerothermal analysis shows that impingement of the bow shock wave on the vehicle and engine noise produce high fluctuating pressures and local heat fluxes. Maximum temperatures will exceed 2700 F (1480 C) at the top of the ascent trajectory and engine sound levels will exceed 170 dB at takeoff. As a result, loads due to engine acoustics and shock impingement dominate the design of many transatmospheric vehicle skin panels. Author

N95-19165# Defence Research Agency, Farnborough, Hampshire (England).

ADVANCED STATISTICAL ENERGY ANALYSIS

K. H. HERON *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 8 p (SEE N95-19142 05-71) Sep. 1994 (AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

A high-frequency theory (advanced statistical energy analysis (ASEA)) is developed which takes account of the mechanism of tunnelling and uses a ray theory approach to track the power flowing around a plate or a beam network and then uses statistical energy analysis (SEA) to take care of any residual power. ASEA divides the energy of each sub-system into energy that is freely available for transfer to other sub-systems and energy that is fixed within the sub-systems that are physically separate and can be interpreted as a series of mathematical models, the first of which is identical to standard SEA and subsequent higher order models are convergent on an accurate prediction. Using a structural assembly of six rods as an example, ASEA is shown to converge onto the exact results while SEA is shown to overpredict by up to 60 dB. Author

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EARTH RESOURCES AND REMOTE SENSING

Includes remote sensing of earth resources by aircraft and spacecraft; photogrammetry; and aerial photography.

N92-22799# Naval Oceanographic and Atmospheric Research Lab., Monterey, CA. Atmospheric Directorate.

A VIRTUAL SENSOR FOR EVAPORATION DUCTS: THE IMPACT OF DATA UNCERTAINTIES

JOHN COOK *In* AGARD, Remote Sensing of the Propagation Environment 10 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Space and Naval Warfare Systems Command (AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

For this application, virtually sensed data is defined as the output from a combination of satellite based remote sensing instruments that have been blended with data from a numerical weather prediction model/data assimilation system and processed by an algorithm. Such a 'virtual sensor' is described to assess evaporation ducts over marine regions. Here, the sensitivity of four evaporation duct height algorithms are examined and the results are expressed in terms of the duct height error versus parameter error. The data used was generated parametrically so that a large variation of environmental conditions could be considered. The errors imposed on the data represent uncorrelated random errors associated with satellite based remote sensing inaccuracies. The study shows that, although the evaporation duct height algorithms have different genealogies, they have similar sensitivities. The conclusions represent a best case scenario because of the omission of some sources of error and the assumption of horizontal homogeneity in the near-surface refractivity field over a typical satellite sensor footprint. Author

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ENVIRONMENT POLLUTION

Includes atmospheric, noise, thermal, and water pollution.

N94-29247# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Inst. fuer Physik der Atmosphaere.

ON THE EFFECT OF EMISSIONS FROM AIRCRAFT ENGINES ON THE STATE OF THE ATMOSPHERE

U. SCHUMANN *In* AGARD, Fuels and Combustion Technology for Advanced Aircraft Engines 19 p (SEE N94-29246 08-25) Sep. 1993 Sponsored by DFG; BMFT; and Commision of the European Communities (AGARD-CP-536) Copyright Avail: CASI HC A03/MF A04

Emissions from aircraft engines include carbon dioxide, water vapor, nitrogen oxides, sulphur components, and various other gases and particles. Such emissions from high-flying global civil subsonic aircraft contribute to anthropogenic climate changes by increase of ozone and cloudiness in the upper troposphere, and by enhanced greenhouse effect. The absolute emissions by air traffic are small (a few percent of total) in comparison to surface emissions. However, the greenhouse effect of emitted water and of nitrogen oxides at cruise altitude is large in comparison to that of the same emissions near the earth's surface because of relatively large residence times at flight altitudes, low background concentrations, low temperature, and large radiative efficiency. At present, it appears that the emissions of nitrogen oxides have changed the background concentration in the upper troposphere in between 40 deg N and 60 deg N by 100 percent, causing an increase of ozone by about 20 percent. Regionally the observed annual mean change in cloudiness is of order 0.4 percent. The resultant greenhouse effect of changes in ozone and thin cirrus cloud cover causes a climatic surface temperature change of the order 0.01 to 0.1 K. These temperature changes are small in comparison to the natural variability. Recent research indicates that the emissions at cruise altitude may increase the amount of stratospheric aerosols and polar stratospheric clouds and thereby

may have an impact on the atmosphere environment, to a yet unknown degree. Air traffic is increasing by about five to six percent per year; fuel consumption grows by about three percent per year. Moreover, the climatic changes due to air traffic enhance other environmental problems originating, e.g., from anthropogenic carbon dioxide or methane emissions. Hence, air traffic induced emissions are of growing importance. This calls for the development of efficient and low-emission propulsion systems and other means to reduce the emissions. This paper surveys the state of knowledge and describes several items of results from recent and ongoing research. Author (revised)

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GEOPHYSICS

Includes aeronomy; upper and lower atmosphere studies; ionospheric and magnetospheric physics; and geomagnetism.

N92-22790# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
REMOTE SENSING OF THE PROPAGATION ENVIRONMENT
Feb. 1992 340 p In ENGLISH and FRENCH Symposium held Cesme, Turkey, 30 Sep. - 4 Oct. 1991
(AGARD-CP-502; ISBN-92-835-0654-5; AD-A247934) Copyright Avail: CASI HC A15/MF A03

Increasing complexity and sophistication of modern military sensor and weapon systems require a more accurate and timely description of the propagation environment for the entire electromagnetic spectrum. Active and passive remote sensing techniques deployed from the ground, airborne platforms, and satellites offer the greatest potential for producing the desired information in a timely manner. The symposium addressed: (1) sensing tropospheric refractivity using propagation measurements and various other remote sensing techniques; (2) ionospheric sensing techniques and interpretation of remotely sensed signatures; (3) sensing of aerosols and other atmospheric parameters important for the propagation of visible and infrared radiation; (4) techniques to measure winds, temperature, liquid water, and humidity in the lower atmosphere; and (5) measurement, inversion, and processing techniques. For individual titles, see N92-22791 through N92-22825.

N92-22791# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
REMOTE SENSING OF REFRACTIVITY STRUCTURE BY DIRECT RADIO MEASUREMENTS AT UHF
HERBERT V. HITNEY *In* AGARD, Remote Sensing of the Propagation Environment 6 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Office of Naval Technology
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

A method is presented that allows the base of a trapping layer to be determined directly from observations of signal strength on a UHF path in the southern California coastal area. The method uses long-term statistics of trapping layer thickness and refractivity gradient in the area. These statistics are used to compute radio signal strength as a function of the base height of the trapping layer using the Naval Ocean Systems Center Radio Physical Optics (RPO) model. The radio path selected is an over-water 148 km path with transmitter and receiver both located 30 m above sea level. The RPO results are used to infer the trapping layer base height directly from observations of received signal strength. This method was applied to a 40-day period of continuous signal strength recordings during which the trapping layer base height was known to vary considerably from near zero to about 1000 meters. Inferred base height versus time is compared to direct meteorological measurements of the base of the temperature inversion in the area of the measurements. Author

N92-22793# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
REMOTE SENSING OF THE EVAPORATION DUCT USING AN X-BAND RADAR
KENNETH D. ANDERSON *In* AGARD, Remote Sensing of the Propagation Environment 9 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Office of Naval Technology
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Results from a unique analytical and measurement effort to assess low-altitude short-range radar detection capabilities in an evaporation ducting environment are presented. Although the measurement effort is ongoing, current results for unstable conditions validate propagation model predictions of reduced radar detection ranges within the radio horizon. In addition, discrepancies between measured and predicted radar data demand a close examination of both meteorological data and surface layer theory. At ranges near and beyond the horizon, radar detection capabilities crucially depend both on the surface layer refractivity profile and on the refractivity profile determined from upper-air observation. An empirical model to merge the surface layer with the mixed layer is discussed. Other discrepancies, which are thought to be caused either by inadequate surface layer modeling or by inadequate surface layer meteorological measurements, suggest the need for an improved surface layer model. Remote sensing of the evaporation duct by radar measurements is not a viable tactical tool. However, the combination of direct surface and upper-air meteorological measurements with remotely sensed radar measurements and with advanced numerical modeling capabilities does provide valuable insight for a better understanding of the atmospheric surface layer and its effects on low-altitude short-range radar detection. Author

N92-22800# Royal Aircraft Establishment, Farnborough (England). Aerospace Div.
ROSE: A HIGH RESOLUTION, AMPLITUDE CODED, HIGH FREQUENCY OBLIQUE IONOSONDE
P. C. ARTHUR, A. H. DICKSON, and P. S. CANNON *In* AGARD, Remote Sensing of the Propagation Environment 7 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

A high quality high frequency oblique ionosonde was developed for use in propagation research and associated studies of the ionosphere. The ionosonde is known as ROSE (Radio Oblique Sounding Equipment) and requires the connection of a specially designed enhancement to a commercially available chirp sounder receiver (RCS-5) manufactured by the BR Corporation in the USA. Two important features are brought about by the addition of this enhancement. First is an increase in the resolution of an ionogram by a factor of approximately three. This allows the fine structure in the ionospheric returns to be detected. Second is color coding of the ionogram according to the amplitude of the received signal. Detailed mode amplitude information and comparisons of the relative strengths of propagating modes can be achieved. Additional features which are provided include display handling and data storage facilities. Author

N92-22801# Massachusetts Univ., Lowell, MA. Center for Atmospheric Research.
THE NEW PORTABLE DIGISONDE FOR VERTICAL AND OBLIQUE SOUNDING
BODO W. REINISCH, D. MARK HAINES, and WALTER S. KUKLINSKI *In* AGARD, Remote Sensing of the Propagation Environment 11 p (SEE N92-22790 13-46) Feb. 1992
(Contract(s)/Grant(s): F19628-90-K-0029)
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

A small low cost digital ionosonde, the Digisonde Portable Sounder (DPS), was developed. It uses 500 microsecond, 10 percent duty factor, wide pulses for vertical sounding and 8.5 microsecond pulses for oblique sounding. Intrapulse coding and pulse compression techniques result in a 67 microsecond resolution for both waveforms. A new autoscaling technique for oblique ionograms inverts the oblique echo traces into midpoint electron density profiles that are modeled as a sum of quasiparabolic layers. Author

N92-22802# Illinois Univ., Urbana-Champaign, IL. Dept. of Electrical and Computer Engineering.
SENSING THE IONOSPHERIC REFLECTION CHANNEL WITH A SOUNDER
K. C. YEH (Illinois Univ. at Urbana-Champaign, Savoy.) and HAIM SOICHER (Army Communications-Electronics Command, Fort Monmouth, NJ.) *In* AGARD, Remote Sensing of the Propagation Environment 10 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

A sounder was designed and constructed to probe the ionosphere for channel properties. The sounder must be capable of probing the ionosphere for wideband response. The implemented sounder consists of a transmitter located in Platteville, Colorado and a receiver located in Urbana, Illinois, separated by a ground distance of 1401 km. The transmitter and receiver are both PC controlled to sound the ionosphere at 6 frequencies selectable by the experimenter in the range of 5 to 15 MHz. The sounder can be commanded by a central PC in the laboratory to work in either the ranging mode or the probing mode. In the ranging mode, the time delay is measured; in the probing mode, the quadrature components (or amplitude and phase) are measured. Reported here are some experimental results obtained by using this sounder. Specifically, some properties of the time dependent transfer function of the channel are described. Author

N92-22803# Hull Univ. (England). Communications Research Group.
ADAPTIVE REMOTE SENSING OF THE IONOSPHERE TO MINIMISE SPECTRAL INTRUSION
M. GALLAGHER and M. DARNELL *In* AGARD, Remote Sensing of the Propagation Environment 16 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Science Research Council; Roke Manor Research Ltd.; Siemens-Plessey Defence Systems; and RAE
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

Suggested here is a rationale for future remote sensing systems, using as an example an economical sounding system that employs standard radio system elements. The proposed rationale is based upon a generic architecture which can maximize the information gathered with the minimal active radiation of EM energy. The system described can passively monitor the output from proprietary 'chirp' sounders; it also has the additional capability of radiating its own sounding signals to complement the information gathered from passive monitoring. The active sounding takes the form of a segmented swept FM (SSFM) system. The profile of the sounding signal is produced digitally and can take a number of formats, which include simple linear FM ('chirp') as well as other profiles that are inherently tolerant to other specific propagation problems that exist within the ionosphere; for example, the effects of Doppler shift can be minimized through the use of hyperbolic FM. The sounding system adaptively uses sequences that can sound the channels allocated to the communication system as well as frequency ranges of high importance, such as regions near to the maximum usable frequency (MUF) and the lowest usable frequency (LUF). The intelligent and adaptive use of such scanning techniques means that spectrum pollution is minimized, while the information gathered is maximized. Author

N92-22804# Illinois Univ., Urbana, IL. Wave Propagation Lab.
A REVIEW OF VARIOUS TECHNIQUES FOR COMPUTERIZED TOMOGRAPHIC IMAGING OF THE IONOSPHERE
T. D. RAYMUND *In* AGARD, Remote Sensing of the Propagation Environment 10 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

By using some new tomographic techniques for ionospheric electron density imaging, it may be possible to inexpensively (relative to incoherent scatter techniques) image ionospheric electron density in a vertical plane several times per day. Here, the basic geometry of the problem is reviewed and various techniques are discussed. The satellite-receiver geometry used to measure the total electron content causes the data to be incomplete; that is, the measured data do not contain enough information to completely specify the ionospheric electron density distribution in the plane between the satellite and the receivers. Most of the proposed techniques include some method designed to overcome this problem. Applications of these techniques made to simulated and real data and the results are compared and discussed. Author

N92-22805# University Coll. of Wales, Aberystwyth (United Kingdom). Dept. of Physics.
MAPPING ELECTRON CONTENT AND ELECTRON DENSITY IN THE SUB-AURORAL IONOSPHERE
I. K. WALKER, S. E. PRYSE, C. D. RUSSELL, D. L. RICE, and L. KERSLEY *In* AGARD, Remote Sensing of the Propagation Environment 12 p (SEE N92-22790 13-46) Feb. 1992 Sponsored in part by National Radio Propagation Programme and Science Research Council
(Contract(s)/Grant(s): AF-AFOSR-0378-87)
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

Applications involving radio waves propagating through the ionosphere are subject to errors due to the effects of the medium. For several of these effects, the electron content along the propagation path is a key parameter. At high altitudes, steep gradients in electron content resulting from electron density variations in the vicinity of the ionospheric trough are of particular importance. Described here are two methods of mapping electron content and electron density in the sub-auroral ionosphere over northern Europe. The first experiment yields measurements of differential carrier phase from which estimates can be made of the total electron content as a function of latitude for each pass of the NNSS satellites monitored. Calibration to obtain absolute values is achieved using spot data from a co-located receiving system for Global Positioning System (GPS) satellites or by means of ionosonde foF2 values and a slab thickness model. Results are presented illustrating behavior of the ionospheric trough. A second experimental campaign used the simultaneous observations of the NNSS satellites at four stations covering a latitudinal range of some 8 degrees. The resulting measurements of electron content from some 30 satellite passes were used in a reconstruction algorithm to map the electron density on a two dimensional grid. The potential usefulness of tomographic techniques in ionospheric sensing is discussed in light of the results obtained. Author

N92-22806# Netherlands Foundation for Radio Astronomy, Dwingelo (Netherlands).
IONOSPHERE AND TROPOSPHERE SEEN THROUGH A RADIO INTERFEROMETER
T. A. TH. SPOELSTRA *In* AGARD, Remote Sensing of the Propagation Environment 10 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Netherlands Organization for Applied Scientific Research TNO
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Very Long Baseline Interferometry (VLBI) is sensitive to integrated effects along the line of sight. Provision of high quality information about the characteristics of the propagation environment is, therefore, inherent to this technique. The way this technique is generally used also enables the determination of these characteristics with a high time resolution, which makes it useful for the study of irregularities in the medium. Described here are the possibilities and limitations of this technique for ionospheric sensing and sensing of tropospheric refractivity. This technique is compared to some others used to derive the same information. The requirements for data handling and processing techniques are described, as well as the available 'tools'. Author

N92-22807# Illinois Univ., Urbana-Champaign, IL. Dept. of Electrical and Computer Engineering.
RADAR INTERFEROMETRIC TECHNIQUES FOR INVESTIGATING FIELD-ALIGNED IONOSPHERIC PLASMA IRREGULARITIES
F. SURUCU and E. KUDEKI *In* AGARD, Remote Sensing of the Propagation Environment 9 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

One-dimensional interferometric radar systems with receiver baselines directed in magnetic north-south and east-west directions were used to study the anisotropy and inhomogeneity characteristics of ionospheric irregularities. In equatorial electrojet aspect sensitivity measurements conducted at Jicamarca, angular spectrum widths as small as approx. 0.05 degrees were resolved. The cross field structures and dynamics of electrojet irregularities were investigated using an interferometric imaging technique. Author

N92-22808# Nebraska Univ., Lincoln, NE. Dept. of Electrical Engineering.

ACTIVE REMOTE SENSING OF THE IONOSPHERE AND THE EARTH SURFACE IRREGULARITIES

EZEKIEL BAHAR *In* AGARD, Remote Sensing of the Propagation Environment 12 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

Rigorous analyses of complex propagation problems necessitate the use of complete electromagnetic field expansions in three dimensions, the imposition of exact boundary conditions and the application of precise analytical procedures. The complete modal expansion of the horizontally and vertically polarized electromagnetic fields (Transverse Electric and Transverse Magnetic) consists of the radiation term, the lateral wave term, and the trapped waveguide modes. The tangential components of the electric and magnetic fields must be continuous at each of the interfaces of the irregular stratified media. Since the field expansions do not necessarily converge uniformly on the irregular boundaries of the stratified media, Green's theorems should be used to avoid interchanging orders of integration (summation) and differentiation. The 'full wave' procedures are used to convert Maxwell's equations into sets of generalized telegraphists' equations for the forward and backward propagating wave amplitudes. Author

N92-22809# Naval Ocean Systems Center, San Diego, CA.

SENSING OF ELF SIGNATURES ARISING FROM SPACE VEHICLE DISTURBANCES OF THE IONOSPHERE

JACK Y. DEA (Naval Ocean Systems Center, San Diego, CA.), WILLIAM VANBISE (Magtek Lab., Reno, NV.), ELIZABETH A. RAUSCHER (Magtek Lab., Reno, NV.), and WOLFGANG-MARTIN BOERNER (Illinois Univ., Chicago.) *In* AGARD, Remote Sensing of the Propagation Environment 11 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

Observations of Extremely Low Frequency (ELF) signatures during exit or reentry of space vehicles through the ionosphere are presented. The two modes regularly observed gave signals that peaked at 5.6 Hz and 11.2 Hz. The evidence points to the lower ionosphere, i.e., the D- and E-layers, as the generator of the signals. The measurements were performed using ground-based multi-turn coil sensors located in Reno and San Diego. The nature of these signals is unclear at present but it is surmised that we are detecting either the evanescent fields of hydromagnetic waves traveling in the ionosphere or the oscillating geomagnetic field associated with these hydromagnetic waves. Author

N92-22810# Naval Ocean Systems Center, San Diego, CA.

SENSING OF SEISMO-ELECTROMAGNETIC EARTHQUAKE PRECURSOR RADIATION SIGNATURES ALONG SOUTHERN CALIFORNIA FAULT ZONES: EVIDENCE OF LONG DISTANCE PRECURSOR ULF SIGNALS OBSERVED BEFORE A MODERATE SOUTHERN CALIFORNIA EARTHQUAKE EPISODE

JACK Y. DEA (Naval Ocean Systems Center, San Diego, CA.), CHARLES I. RICHMAN (Naval Ocean Systems Center, San Diego, CA.), and WOLFGANG-MARTIN BOERNER (Illinois Univ., Chicago.) *In* AGARD, Remote Sensing of the Propagation Environment 8 p (SEE N92-22790 13-46) Feb. 1992 Previously announced in IAA as A92-17553
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Observations of broadband ULF signals before and after an earthquake are presented. The particular quake in question was the Upland quake of 17 Apr. 1990, which was centered 200 km north of San Diego. The signals were detected with the vertically oriented search coil sensor and not with the horizontally oriented sensors, which suggests a disturbed ionosphere as the most likely source of these signals. The large prequake ULF activity, the rapid decay of ULF activity after the quake, and the absence of any geomagnetic storms indicate a good correlation of the ULF activity with the Upland quake. An interpretation of radio observations of seismic activity is presented and extended to earthquake precursor studies. Author

N92-22811# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.

REMOTE SENSING OF AEROSOL EXTINCTION USING SINGLE-ENDED LIDARS

J. H. RICHTER, H. G. HUGHES, and M. R. PAULSON *In* AGARD, Remote Sensing of the Propagation Environment 5 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Office of Naval Technology
(AGARD-CP-502) Copyright Avail: CASI HC A01/MF A03

A review is presented of past efforts to determine atmospheric extinction from single-ended lidar measurements of backscatter, and the assumptions made concerning the backscatter/extinction relationships. The degree to which the aerosols within the convectively mixed atmosphere can be expected to be horizontally homogeneous is also discussed. The conclusions are that unless the extinction/backscatter relationship is known, or that the atmosphere is horizontally homogeneous over the propagation path, the accuracies of extinction coefficients determined by a single-ended lidar cannot be assured. D.R.D.

N92-22812# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, The Hague (Netherlands). Physics and Electronics Lab.

PROBING OF THE ATMOSPHERE WITH LIDAR

G. J. KUNZ *In* AGARD, Remote Sensing of the Propagation Environment 11 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A03/MF A03

Lidar (optical radar) is a generally accepted technique which is used for remote sensing of atmospheric properties over ranges of kilometers to within a few microseconds. Different inversion techniques used to derive the required information from the lidar signal are discussed. The lidar properties determine which kind of information can be obtained. An overview of results obtained with two different lidar systems is presented. The results include the assessment of the systems, long term studies of the vertical infrared structure of the atmosphere, and fast dynamic processes. D.R.D.

N92-22813# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.

LIDAR REMOTE SENSING TECHNIQUES FOR DEVELOPING AND EVALUATING ATMOSPHERIC AEROSOL MODELS

D. R. JENSEN, H. G. HUGHES, and M. R. PAULSON *In* AGARD, Remote Sensing of the Propagation Environment 6 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by Office of Naval Technology
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

A technique was developed by which lidar (optical radar) returns can be used to adjust simultaneously observed/modeled aerosol size distributions to represent existing atmospheric conditions. The technique was used to evaluate the U.S. Navy Maritime Aerosol Model (NAM) and the U.S. Navy Oceanic Vertical Aerosol Model (NOVAM). The evaluation of NOVAM indicated that, when scaled to visibility, good agreement exists between the lidar scaled extinction and backscatter coefficients and the predicted profiles. While adjustments of the NAM aerosol number densities can be made to match the modeled S(R) profiles to that measured by lidar in the first few meters above the surface of the ocean, the large adjustments for low wind speed indicates that the modeled aerosol size distribution shape near the ocean surface may not be correct. D.R.D.

N92-22816*# Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA.

REMOTE SENSING OF THE ATMOSPHERE BY MULTI-CHANNEL RADIOMETERS

FARAMAZ DAVARIAN *In* AGARD, Remote Sensing of the Propagation Environment 8 p (SEE N92-22790 13-46) Feb. 1992 Sponsored by NASA, Washington
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

To characterize Earth/space communication links, the Jet Propulsion Laboratory's (JPL's) Radiowave Propagation Program supports a number of propagation studies. Low-availability satellite links and their propagation vagaries at Ka and millimeter-wave bands constitute a major effort within this program. Since 1987, this program has funded the Wave Propagation Laboratory (WPL) of the National Oceanic and Atmospheric Administration (NOAA) to conduct multiple-frequency radiometric observations of the

atmosphere. Measurements of atmospheric emission and attenuation at 20, 31, and 90 GHz at different locations are presented. Single-station and joint-station statistics are derived. A linear regression scheme for the prediction of fade statistics in one channel using fade data from the other two channels is presented. Author

N92-22817# Atmospheric Sciences Lab., White Sands Missile Range, NM.
OPTICAL REFRACTION IN THE ATMOSPHERIC SURFACE LAYER
JAMES B. GILLESPIE and DAVID H. TOFSTED *In* AGARD, Remote Sensing of the Propagation Environment 7 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

The nature was studied of atmospheric refraction and criteria was developed when refraction may cause errors in tank gunnery in deserts. Refraction can be remotely sensed as a function of time through point to point measurements of the elevation of a distant object relative to the atmospheric neutral events that occur approximately 1/2 hr before sunset and 1/2 hr after sunrise. The vertical position change of a distant object can be measured using either another object close enough to the observer that effects will be minimal (thus providing a fixed reference point) or a theodolite that has its own internal reference through the leveling bubble. Extensive measurements were made of diurnal variations in elevation of distant objects at White Sands Missile Range (WSMR), NM. Lessons learned from these experiments include accounting for numerous potential error sources when taking readings using theodolites and the photographic techniques necessary to cope with changing light levels and atmospheric turbulence effects. Measurements were made at other locations that exhibit similar vertical shifting characteristics. A surface energy budget model was developed to predict refraction situations based on meteorological measurements. Author

N92-22818# Atmospheric Sciences Lab., White Sands Missile Range, NM.
INVERTING RADIOMETRIC MEASUREMENTS WITH A NEURAL NETWORK
EDWARD M. MEASURE, YOUNG P. YEE, JEFF M. BALDING, and WENDELL R. WATKINS *In* AGARD, Remote Sensing of the Propagation Environment 6 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

A neural network scheme for retrieving remotely sensed vertical temperature profiles was applied to observed ground based radiometer measurements. The neural network used microwave radiance measurements and surface measurements of temperature and pressure as inputs. Because the microwave radiometer is capable of measuring 4 oxygen channels at 5 different elevation angles (9, 15, 25, 40, and 90 degs), 20 microwave measurements are potentially available. Because these measurements have considerable redundancy, a neural network was experimented with, accepting as inputs microwave measurements taken at 53.88 GHz, 40 deg; 57.45 GHz, 40 deg; and 57.45, 90 deg. The primary test site was located at White Sands Missile Range (WSMR), NM. Results are compared with measurements made simultaneously with balloon borne radiosonde instruments and with radiometric temperature retrievals made using more conventional retrieval algorithms. The neural network was trained using a Widrow-Hoff delta rule procedure. Functions of date to include season dependence in the retrieval process and functions of time to include diurnal effects were used as inputs to the neural network. Author

N94-11500# Technische Univ., Brunswick (Germany). Inst. fuer Flugfuehrung.
STABILITY MODEL OF THE ATMOSPHERE
ANDREAS KNUEPPEL, DANIEL MARTENS, and ANDREAS SIEMER (Technische Univ., Hamburg, Germany.) *In* AGARD, Stability in Aerospace Systems 17 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

The atmosphere of the earth is a very complex system covering a wide range of interacting scales. The concept of stability is applied to subsystems thereof where the quantities involved in a stability analysis depend on the particular question to be answered. But all stability considerations share a common basic structure. After giving a short account to the nature of stability investigations, some examples of stability related atmospheric phenomena are presented which are relevant for flight operation. Finally, the impact of atmospheric instability on aircraft performance with special regard to flight safety is illustrated. Author

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METEOROLOGY AND CLIMATOLOGY

Includes weather forecasting and modification.

N92-22819# Colorado Univ., Boulder, CO. Cooperative Inst. for Research in Environmental Sciences.
CLEAR-AIR WIND PROFILERS AS CLOUD MONITORS AND HYDROMETEOR IDENTIFIERS
E. E. GOSSARD (Colorado Univ., Boulder.), S. Y. MATROSOV (National Oceanic and Atmospheric Administration, Boulder, CO.), R. G. STRAUCH (National Oceanic and Atmospheric Administration, Boulder, CO.), and D. C. WELSH (National Oceanic and Atmospheric Administration, Boulder, CO.) *In* AGARD, Remote Sensing of the Propagation Environment 10 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Clear air sensing radars, which are used for wind sounding from surface platforms, are now widely deployed. They are usually designed to measure the Doppler sensed movement of clear air refractive index inhomogeneities, but they also provide an excellent tool for sensing ice and water particles in clouds. These radars usually have a very low detection threshold and long averaging time so that size distributions of particles as small as 100 micrometer diameter with mean vertical fall velocities (V sub f) as small as 0.2/ms can be accurately measured. Data is presented from two events in which clouds form, intensify, and finally produce precipitation. Height profiles are displayed and analyzed as ZRV sub f plots vs. height, where Z is the radar reflectivity factor, R is liquid flux (rain), and V sub f is the mean fall velocity in quiet air derived from the radar measured vertical velocity. It is shown how these radars can provide (1) cloud layer structure above lower overcast; (2) height profiles of liquid mean drop size; (3) the ice water transition level compared with the 0 deg isotherm; (4) height profiles of rain rate; and (5) inferences about the identity of hydrometeors vs. height. Author

N92-22824# Technische Hogeschool, Delft (Netherlands). Faculty of Electrical Engineering.
RECENTLY IMPLEMENTED WEATHER RADAR DATA PROCESSING TECHNIQUE FOR RAIN CELL MODELLING AND GROUND CLUTTER DETECTION
Y. KORBAY and L. LIGTHART *In* AGARD, Remote Sensing of the Propagation Environment 6 p (SEE N92-22790 13-46) Feb. 1992
(AGARD-CP-502) Copyright Avail: CASI HC A02/MF A03

Throughout the last two decades, dramatic changes have been taking place in the field of radar meteorology. The effects of modern digital signal processing techniques should be especially considered. These new technologies present new opportunities in the weather radar research arena. Real-time processing is at present the key problem in this field, because by nature, meteorological targets are distributed in space and occupy a large portion of the spatial resolution cells observed by radar. For this reason, meteorological radars require high data rate recording and effective real-time processing. To solve the data handling and processing problems for weather surveillance radars, a method was initiated. The method makes use of a 'Framing based Radar Data Analysis'. The method shows great potential in the field of rain cell modeling and ground clutter suppression. The first verifications were performed using the off-line experimental data obtained from the operational Delft radar SOLIDAR. Author

N93-29913# MATRA Marconi Space Portsmouth, Hampshire (England).

TACSAT METEOROLOGICAL PAYLOADS

D. HICKMAN *In* AGARD, TacSats for Surveillance Verification and C3I 8 p (SEE N93-29892 11-32) Feb. 1993

(AGARD-CP-522) Copyright Avail: CASI HC A02/MF A03

Information derivable from meteorological satellites are reviewed in terms of their applicability to military use. Potential TACSAT meteorological systems are discussed in terms of GEO and LEO payloads currently in operation. Author

N95-14895# Institute for Aerospace Research, Ottawa (Ontario). Flight Research Lab.

WINTER STORMS RESEARCH IN CANADA

J. IAN MACPHERSON and GEORGE A. ISAAC *In* AGARD, Flight in an Adverse Environment 21 p (SEE N95-14893 03-03) Nov. 1994 Sponsored by Federal Panel on Energy Research and Development; Atmospheric Environment Service; National Research Council of Canada; National Search and Rescue Secretariat, Dept. of National Defence; Boeing Commercial Airplane Co.; and Airbus Industrie

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Canada has undertaken long-term research program to study winter storms in coastal regions, with the objectives of improving their forecast and understanding their embedded mesoscale features, rapid intensification, and microphysical conditions associated with aircraft icing. In cooperation with the Atmospheric Environment Service of Environment Canada (AES), the National Research Council (NRC) Twin Otter and Convair 580 aircraft have been instrumented to measure the motion and thermal structure of the atmosphere and the microphysics of cloud and precipitation. The aircraft have been flown in two Atlantic Storms projects in conditions that pilots usually attempt to avoid. Examples of the hazardous conditions encountered in these research flights are presented in this paper, along with supporting air motion and microphysics data recorded aboard the aircraft. Incidents of airframe icing, turbulence, strong winds and wind shear serve as an introduction to the more detailed treatment of these subjects by subsequent lecturers. Other related subjects covered include research reduced visibility and on-ground icing of aircraft. Information is presented on recent developments in instrumentation for the early recognition and warning of hazardous flight conditions. The paper concludes with a look to the future for coping with winter storms in Canada, including planned research field programs. Author

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LIFE SCIENCES (GENERAL)

N94-28420# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

THE SUPPORT OF AIR OPERATIONS UNDER EXTREME HOT AND COLD WEATHER CONDITIONS [LES OPERATIONS AERIENNES EN ENVIRONNEMENT EXTREME CHAUD/FROID]

Oct. 1993 312 p In ENGLISH and FRENCH Symposium held in Victoria, British Columbia, 17-21 May 1993

(AGARD-CP-540; ISBN-92-835-0721-5) Copyright Avail: CASI HC A14/MF A03

Extreme temperatures, both hot and cold, can severely restrict the ability of aircrew and support personnel to accomplish their missions. Under emergency conditions of bail-out, ejection, and ditching of fixed or rotary-wing aircraft on land or in water, the survival rate of aircrew and passengers is also affected by the intensity of thermal stress experienced and the duration of exposure to the thermal stress. This has all recently been borne out by the experience of intense air operations in the Gulf War. This symposium reviewed the operational conditions experienced under extreme hot and cold weather. The papers presented at this symposium highlighted recent advances in thermal physiology, clothing sciences, personal flying equipment, and microclimate cooling. Emphasis was placed on the potential applications of these advances in situations where thermal stress may confound the efficient achievement of mission objectives. For individual titles, see N94-28421 through N94-28453.

N94-28439# Erlangen-Nuremberg Univ. Childrens Hospital (Germany). Inst. of Forensic Medicine.

PHYSIOLOGICAL INVESTIGATIONS OF THE ISOLATED RAT'S LIVER IN HYPOTHERMIA AND HYPOXIA AND THEIR RELEVANCE IN AIRCRAFT INCIDENTS ABOVE THE SEA

T. DUMSER, M. KRAEMER (Institute of Aviation Medicine, Fuerstenfeldbruck, Germany.), and J. HOEPER *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 11 p (SEE N94-28420 08-51) Oct. 1993

(AGARD-CP-540) Copyright Avail: CASI HC A03/MF A03

Animals have two main methods of adjusting their body temperature. Poikilothermic animals adjust it to the existing ambient temperature, temperature, whereas homoiothermic animals keep temperature at a relatively constant value which is frequently above the ambient temperature; thus, temperature; thus, they able to stay in contrast to poikilothermic animals whose metabolic processes slow down increasingly due to van't Hoff's rule when ambient temperatures are when ambient temperatures are low, rendering sometimes even resulting in low-temperature rigidity. This, however, enables them to survive for a longer period of time in case of a lack of food and/or cold spells. Hibernating animals are something in between. In times of food shortage and in the period of cold weather, they reduce their metabolic processes and lower their body temperature. Without a doubt, man is part of the group of homoiothermic organisms. However, when having a closer look at homoiothermic organisms, it becomes obvious that their body temperature is only constant as far as the body core and the vital organs are concerned - there are fluctuations in the temperature of the extremities, i.e., the outer parts of the body, which are mainly induced by the environment. Consequently, the tissue of these regions of the body is subject to changes in temperature which may be considerable without resulting in permanent damage. Findings, mainly obtained from transplantation medicine, have shown that the organs of the body core need not be damaged irreversibly either, if their temperature is lowered for several hours - on the contrary, they can even be preserved this way for a limited period. Derived from text

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AEROSPACE MEDICINE

Includes physiological factors; biological effects of radiation; and effects of weightlessness on man and animals.

N92-28534# Netherlands Aerospace Medical Centre, Soesterberg (Netherlands).

G-TOLERANCE AND SPATIAL DISORIENTATION: CAN SIMULATION HELP US?

J. SMIT (Netherlands Aerospace Medical Centre, Soesterberg.) and ROBERT E. VANPATTEN (Van Patten, Robert E., Bellbrook, OH) *In* AGARD, Piloted Simulation Effectiveness 7 p (SEE N92-28522 19-01) Feb. 1992

(AGARD-CP-513) Copyright Avail: CASI HC A02/MF A03

Pilots of modern fighter aircraft are endangered by high G-forces, loss of situational awareness, and spatial disorientation. In order to prepare aircrew for these factors, ground based training facilities simulating some aspects of the relevant phenomena are used. The human centrifuge has proven to be rather effective in increasing G-tolerance, especially in conditions of high onset rate. Unrealistic simulations caused by the small radius of rotation in centrifuges can generate disturbing vestibular stimulation. During the development of the human centrifuge at the Netherlands Aerospace Medical Center an investigation was undertaken to find methods to suppress these detrimental effects. Smoothing of centrifuge motion and a realistic, computer-generated outside-vision system proved to be effective measures. Realistic target tracking and a cockpit-like environment are factors which enhance transfer of training. Author

N93-11283# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

ALLERGIC, IMMUNOLOGICAL AND INFECTIOUS DISEASE PROBLEMS IN AEROSPACE MEDICINE [LES PROBLEMES CAUSES PAR LES MALADIES ALLERGIQUES, IMMUNOLOGIQUES ET CONTAGIEUSES EN MEDECINE AEROSPATIALE]

Apr. 1992 211 p In ENGLISH and FRENCH Symposium held in Rome, Italy, 21-25 Oct. 1991
(AGARD-CP-518; ISBN-92-835-0664-2; AD-A252141) Copyright Avail: CASI HC A10/MF A03

These proceedings include the technical evaluation report, the opening address, and 36 papers of the symposium. The theme of the symposium was the fight against infectious diseases, mainly the vaccine-preventable ones, and the study of inhalent allergic diseases. Enormous development in the last few years has allowed us to understand and prevent many pathological conditions, whereas the setting up of laboratory tests has allowed us to monitor with great precision the immune function which may be depressed by the environmental stimuli to space or military flight. Lastly, the development of military and civilian air travel, which favors the spreading of infectious and parasitic diseases, requires the setting up of correct prophylactic measures. For individual titles, see N93-11284 through N93-11318.

N93-11284# Eidgenoessische Technische Hochschule, Zurich (Switzerland). Space Biology Group.

SPACE FLIGHT AND IMMUNE SYSTEM

A. COGOLI *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 10 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A02/MF A03

Depression of lymphocyte response to mitogens in cosmonauts after spaceflight was reported for the first time in the early seventies by Soviet immunologists. Today we know that depression of lymphocyte function affects at least 50 percent of space crew members. Investigations on the ground on subjects undergoing physical and psychological stress indicate that stress is a major factor immune depression of astronauts. This despite the fact that weightlessness per-se has a strong inhibitory effect of lymphocyte activation in-vitro. Although the changes observed never harmed the health of astronauts, immunological changes must be seriously investigated and understood in view of long duration flights on space stations in an Earth orbit and to other planets like Mars and the Moon. Author

N93-11285# Defence and Civil Inst. of Environmental Medicine, North York (Ontario).

MECHANISMS OF IMMUNE FAILURE IN BURN INJURY

BRIAN G. SPARKES *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 12 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A03/MF A03

The burden on military medical services in handling burn casualties is daunting as all physiological systems will become affected. Severe burns in a battlefield setting have a very low salvage rate, to a great degree because of the immune failure which invariably develops. Evaluations of responses of lymphocytes taken from burn patients over several weeks following the burn (greater than 30 percent TBSA), have revealed that the immune failure which follows thermal injury involves T cell activation events. Interleukin 2, which is normally produced by activated T lymphocytes, is very poorly produced by cells cultivated in vitro taken from non-surviving patients, whereas some production continues, although at below normal levels, in patients who ultimately survive their injury. IL2 exogenously added to lymphocyte cultures enhances the proliferation of cells from surviving patients but gives no such help to cells from nonsurvivors. The TAC portion of the IL2 receptor (IL2R alpha), expressed on the T cell surface, appears to be responsible for this difference, as the number of lymphocytes able to express ILR2 alpha falls post-burn. A lipid protein complex (LPC) produced in skin by burning has been shown to inhibit the immune response in vivo and the growth of IL2-dependent lymphocytes in culture. Cerium nitrate, applied topically to the burn patient, is thought to fix the LPC in the burn eschar and prevents its entry into the circulation. In a study of 10 patients, bathed in cerium nitrate, some T lymphocyte activities were found to be in the normal range rather than suppressed. Such a treatment promises to be useful in improving chances of survival in severe burn injury. Author

N93-11286# Turin Univ. (Italy).

CLINICAL TYPES OF HEPATITIS B

MARIO RIZZETTO and ROBERTO NISINI (Divisione Aerea Studi Ricerche e Sperimentazioni, Pratica di Mare, Italy) *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 7 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A02/MF A03

Hepatitis B is a parenterally and sexually transmitted disease of global importance. The disease runs more frequently a subclinical and anicteric course, with a significative rate of cases that become chronic. Chronic hepatitis may progress to cirrhosis or cancer. The strategies by which Hepatitis B can be diminished and eventually eliminated are: immunization, measures to prevent exposure to infective blood or blood derivatives, and education (in particular awareness that hepatitis B is a sexually transmitted disease). Author

N93-11287# Aerospace Medical Research Labs., Brooks AFB, TX. Epidemiologic Research Div.

VIRAL HEPATITIS IN THE US AIR FORCE, 1980 - 1989

M. D. PARKINSON, R. W. STOUT, D. R. MAHON, W. F. CLARDY, R. W. WARNER, M. E. WESTON, and W. H. WOLFE *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 2 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A01/MF A03

Viral hepatitis and its acute and chronic complications continue to pose significant threats to the readiness of military personnel. Knowledge about the specific viral agents and their routes of transmission are important in developing prevention strategies. A recent analysis of hepatitis in the U.S. Navy for the period 1975-1984 is reviewed. In order to better characterize the risk of viral hepatitis among Air Force personnel, a comprehensive review of inpatient and quarters data for hepatitis A, B and 'non-A, non-B' were reviewed from Air Force medical treatment facilities worldwide for the period 1980-1989. Following a discussion of the study methodology, preliminary data and hepatitis type-specific demographic risk variables are discussed. Preliminary results from a hepatitis serosurvey (A, B, and C antibody with use of a supplemental validating assay) of the subset of the study cohort who are currently on active duty are briefly reviewed. Author

N93-11288# Zurich Univ. (Switzerland). Div. of Epidemiology and Prevention of Communicable Diseases.

HEPATITIS A AND HEPATITIS B: RISKS COMPARED TO OTHER VACCINE PREVENTABLE DISEASES AND IMMUNIZATION RECOMMENDATIONS

R. STEFFEN *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 4 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A01/MF A03

The incidence rate of hepatitis A is 3(-6)/1000 per month of stay in a developing country in unprotected travelers. Trampers and other persons feeding themselves under bad hygienic conditions have a rate of 20/1000. In many industrialized countries, persons below the age of 50 years have a seroprevalence rate of anti-HAV less than 20 percent. Hepatitis A morbidity and mortality in travelers is far greater than the one of any other vaccine preventable infection in travelers, with the exception that hepatitis B shows a slightly greater mortality in expatriates. Future studies will determine the role of hepatitis C and E. Typhoid fever shows an incidence rate of 0.3/1000 in foreigners on the Indian subcontinent, and in many parts of North and West Africa, excluding Tunisia, in other parts of the third world it is tenfold lower. In poliomyelitis, tetanus, diphtheria, cholera, rabies, and Japanese encephalitis, the incidence rate is greater than or equal to 0.002/1000. Author

N93-11289# Camerino Univ., Camerino (Italy). Dept. of Hygiene.

VACCINATION AGAINST HEPATITIS B: THE ITALIAN STRATEGY

A. R. ZANETTI, J. GRAPPASONNI, E. TANZI (Milan Univ., Italy), and L. ROMANO (Milan Univ., Italy) *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A01/MF A03

Viral hepatitis type B is a major worldwide public health problem. Infection with the hepatitis B virus (HBV) may progress to chronic liver disease including chronic active hepatitis, cirrhosis, and hepatocellular carcinoma. Moreover, it has been estimated that between 200 and 300 million individuals in the world are chronic carriers of HBV. The availability of safe and effective vaccines allows the establishment of immunization programs aimed at the elimination of hepatitis B and the reduction of morbidity and mortality due to its sequelae. The topics covered include the following: (1) vaccines against hepatitis type B; (2) safety, immunogenicity, and efficacy of hepatitis B vaccines; (3) strategies for control of hepatitis B by immunization; and (4) hepatitis B vaccination in Italy. Author

N93-11290# World Health Organization, Geneva (Switzerland). Global Programme on AIDS.

HIV INFECTION IN THE NINETIES

LARS O. KALLINGS *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 5 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A01/MF A03

By the year 2000, a cumulative global total of 30 to 40 million men, women, and children are projected to have been infected with HIV. This will present a 3 to 4 times increase of the present total. Currently, it is estimated that about 5000 persons are newly infected daily. Worldwide, the predominant and increasing mode for transmission is by heterosexual intercourse. Therefore, the number of infected women will equal that of men. Consequently, more infants will be infected by their mothers and more infants will be orphaned as their parents die of AIDS. By the end of the 1990's, over one million adults, most of them in developing countries. Although the majority of HIV infections are currently occurring in Sub-Saharan Africa, the annual number of HIV infections in Asia is projected to exceed that in Africa during the 1990's. Also in industrialized countries, the proportion of heterosexual transmission is increasing, and AIDS is becoming one of the predominant causes of death in young men and women. In spite of promising scientific progress, vaccines and therapeutic drugs are not expected to have any major impact on the global development of the pandemic during the 1990's. The World Health Organization (WHO) is promoting behavioral changes, condom use, and control of other sexually transmitted diseases as the most important preventive measures. Insight into the dynamics of the HIV/AIDS pandemic and into the growing understanding of the main factors which are fuelling the continued and increasing HIV transmission is given. A short survey of the epidemiological background, the current trends, and the forecasts of the directions of the epidemic during the next decade are presented. Author

N93-11291# Walter Reed Army Medical Center, Washington, DC. Div. of Retrovirology.

AIDS/HIV IN THE US MILITARY

DONALD S. BURKE and EDMUND C. TRAMONT *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 6 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A02/MF A03

HIV infection (AIDS) burst upon the scene a decade ago. Because it is a sexually transmitted disease that infects blood and kills its victim, it is military relevant and will impact on all aspects of the military. The USAMRDC as Lead Agent for Infectious Disease Research in the DoD has developed a comprehensive approach to address military concerns: surveillance of infection rates (intelligence) around the world and in the military; behavioral research to develop more effective means of education to change behavior; and biological research to develop a quick and easy field test, and a vaccine or drug to prevent the disease from occurring despite exposure. Its success will influence the success of the Army in the future. Author

N93-11292# Aerospace Medical Research Labs., Brooks AFB, TX. Epidemiologic Research Div.

ESTIMATES OF HUMAN IMMUNODEFICIENCY VIRUS (HIV) INCIDENCE AND TRENDS IN THE US AIR FORCE

RONALD D. WARNER, ROBERT E. MATHIS, MARY E. WESTON, LARRY R. BIGBEE (Defense Manpower Data Center, Monterey, CA.), CRAIG W. HENDRIX (Air Force Medical Center, Lackland AFB, TX.), and DANIEL R. LUCEY (Air Force Medical Center, Lackland AFB, TX.) *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 5 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A01/MF A03

Between early 1986 and February 1991, over 700,000 United States Air Force (USAF) active duty personnel had been screened for antibodies to the Human Immunodeficiency Virus (HIV). All HIV-infected patients are evaluated at Wilford Hall USAF Medical Center, and staged using the Walter Reed scheme. Two total-force screenings were conducted prior to October 1990. The USAF case registry is maintained by the Epidemiological Research Division. Computer support for incidence calculations is provided by the Defense Manpower Data Center. During the first screening (February 1986-September 1988), 721 HIV-positive personnel were detected from a USAF population of approximately 607,000. The estimated seroprevalence was 1.2/1000. From the second screening 206 positive individuals were detected among approximately 571,000 personnel. As of January 1991, among the total 942 HIV-positives, only 29 were female. Three hundred and fifty-one (37.3 percent) remained on active duty in the US; 296 (31.5 percent) were on temporary disability retirement lists; 193 (20.5 percent) had separated or retired; and 101 (10.7 percent) had died. From June 1987 through June 1990, the estimated incidence of HIV infection in USAF personnel declined from 0.19 to 0.17/1000 person-years. The rate for males in June 1987 was estimated at 0.21/1000 person years. In all, the highest rate was among black males. In October 1985, the US Department of Defense (DOD) mandated that all applicants for military service be tested for evidence of antibodies to the human immunodeficiency virus (HIV). This testing continues, and if they test-positive, applicants are denied entry. Testing of those already in the US military services began soon afterward. Between early 1986 and February 1991, over 700,000 active-duty US Air Force (USAF) personnel were tested for the presence of HIV antibodies. In addition to two total-force (USAF, USAF Reserves, and Air National Guard) screenings prior to October 1990, USAF personnel have been tested in conjunction with: evaluation and treatment for other sexually transmitted diseases, routine and periodic physical examinations, enrollment in drug or alcohol rehabilitation programs, orders to permanent overseas assigments, and clinically-indicated medical reasons. The 1987-1990 HIV incidence estimates are discussed in a relatively young, mobile male population by age, ethnicity/race, sex, and occupational category at time of positive HIV antibody test. Author

N93-11293# Rome Univ. (Italy). Dept. of Allergy and Clinical Immunology.

SILENT HIV INFECTION

FERNANDO AIUTI, FABRIZIO ENSOLI, VALERIA FIORELLI, IVANO MEZZAROMA, ELENA PINTER, EMMA GUERRA, and GIUSEPPE LUZI *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 4 p (SEE N93-11283 02-52) Apr. 1992
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The period of latency between infection by the human immunodeficiency virus type-1 (HIV-1) and the production of specific antibodies to viral antigens may be prolonged and, occasionally, may last for years. This condition of seronegative infection could represent a serious risk of viral transmission from subjects who are unaware of their status. However, whether these individuals are actually infectious, especially through body fluids, has not been clarified. We have performed a prospective study in 65 high risk individuals seronegative for HIV-1 antibodies for a prolonged period of time. Twelve of them (18 percent) were shown to be carriers of HIV-1 proviral sequences by the polymerase chain reaction (PCR). The virus was isolated from nitrogen-stimulated peripheral blood lymphocytes (PBMC) in five out of ten subjects tested since the first positive PCR. In two of them, virus could also be isolated from cell free plasma, subsequently they remained seronegative

during 10 months of follow-up. These data indicate that delayed seroconversions may be associated with productive infection, suggesting that mechanism(s) other than viral latency may be responsible for the absence of antibody responses to HIV-1 proteins. Furthermore our findings suggest that prolonged seronegative individuals can transmit HIV-infection through their body fluids. Author

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HIV VARIABILITY AND PERSPECTIVES OF A VACCINE

P. VERANI, S. BUTTO, B. TADDEO, M. FEDERICO, and G. B. ROSSI *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 5 p (SEE N93-11283 02-52) Apr. 1992

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Since Human Immunodeficiency Virus (HIV) was identified as the causative agent of Acquired Immunodeficiency Syndrome (AIDS) the pressing challenge that researchers are facing is the development of a vaccine against this disease. Although progress has been made in the study of the biology of HIV faster than for any other virus, the development of an effective vaccine has been slowed by the peculiar features of HIV. The difficulties standing before a rationale approach to vaccine design are: (1) the ability of the virus to rapidly change its genome sequency; (2) its spreading from cell to cell; (3) its ability to establish latent infection integrating its genome into that of the target cell without expressing any viral genes and, thus remaining hidden inside the infected cell; and (4) its insidious attack on the immune system upon which a vaccine depends in order to be effective. The design of a rationale approach to a vaccine is discussed. Author

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IMMUNOLOGICAL PARAMETERS IN CURRENT AND FORMER US AIR FORCE PERSONNEL

WILLIAM H. WOLFE, JUDSON C. MINER, and JOEL E. MICHALEK *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 5 p (SEE N93-11283 02-52) Apr. 1992

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Major advancements have been made in the laboratory assessment of the immune system over the past decade. There has been a proliferation of sophisticated techniques to measure the number and functional capacity of subsets of lymphocytes and other cellular elements of the immune system. Unfortunately, the space of this technology has made it difficult for many practicing physicians to develop and maintain an understanding of these new tests. Additionally, appropriate reference values for these tests in 'normal' populations are unclear and little has been done to assess the effects of factors such as age, race, and lifestyle on these measures of immunity. Laboratory assays are available to assess both the counts of the various cellular elements of immunity in the peripheral blood as well as the functional capacity of many of these cells. Tests of delayed cutaneous hypersensitivity are based on techniques used in allergy testing and tuberculosis control. After antigens such as Trichophyton or Candida are injected intradermally, the skin's reactivity correlates with the recall sensitivity of the T cells to each antigen used. Counts of total T lymphocytes (CD2 cells) and B lymphocytes (CD20 cells) are decreased in immune deficiency conditions and are elevated with lymphoproliferative diseases. The helper/inducer T lymphocytes (CD4 cells) are commonly decreased in progressive HIV infection and are increased in autoimmune disorders. The suppressor T cells (CD8) are increased in some viral infections and immunodeficiency states. The CD4/CD8 ratio is a commonly used measure of immune system capability. Tests of activated T lymphocytes (CD25 cells) assess the presence of stimulated T lymphocytes. Unstimulated T cells do not react to this test. This is a useful test in identifying the presence of lymphoproliferative disorders. Count of total lymphocytes is also made. Tests of the functional status of the cellular components of the immune system assess the response of the cells in the peripheral blood to stimulation with various mitogens such as phytohemagglutinin. These test measure the cells' capability to become activated by external stimuli. The natural killer cell assay measures the body's lytic response to foreign tissue cells both before and after stimulation with interlukin. This response is decreased with impaired natural immunity. Standard quantitative measurements of immune globulins (IgA, IgG, and IgM) are also useful in the assessment of immune functions. They measure the ability of specific B lymphocytes to secrete specific classes of antibody. A useful approach to the categorization of several of the quantitative and functional tests of immunity is shown. The tests provide a comprehensive assessment. As part of a comprehensive epidemiologic study of current and former Air Force personnel, an extensive assessment of the immune system was conducted by a single immunology reference laboratory using stringent quality control standards. All of the tests described above were used in this study. The demographic characteristics of these study subjects are displayed. All of the subjects were middle-aged males, most of whom did not currently smoke tobacco. Nearly 80 percent of them currently drink alcoholic beverages. Author

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EARLY MARKERS OF HIV INFECTION AND SUBCLINICAL DISEASE PROGRESSION

M. J. DOLAN, D. R. LUCEY, C. W. HENDRIX, G. P. MELCHER, G. A. SPENCER, and R. N. BOSWELL *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 6 p (SEE N93-11283 02-52) Apr. 1992

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Human Immunodeficiency Virus (HIV) infection in U.S. Air Force personnel between 1985 and 1989 was examined through a mandatory serologic survey, and through annual examination of infected patients. CD4+ cell counts were determined by flow cytometry; Beta 2 microglobulin and neopterin were measured by immunoassay. During this period, 933 cases were found, of which 161 were documented seroconversions, giving an incidence rate of 15.6/100,000 person-years. For patients with greater than 400 CD4 cells/microliter, the rate of initial occurrence of opportunistic infection was 1 percent and 4 percent at 1 and 2 years, respectively. HIV infected persons with less than 400 CD4+ cell/microliter, in contrast, had rates of 21 percent at 1 year and 36 percent at 2 years. In a cross-sectional study, Beta 2 microglobulin concentration was shown to increase in both the serum and spinal fluid of patients infected with HIV as their blood CD4 numbers declined. Neopterin levels in serum and spinal fluid showed a similar trend, with significantly lower neopterin concentrations in the group that had greater than 1000 CD4+ T cells compared to the 0-600 CD4+ cell group. Longitudinal studies included correlation of HIV p24 antigen with CD4 counts over a one year period. The p24 antigen-positive group has a 21 percent decline in CD4+ T cells, while the antigen negative group has a 14 percent decline. Specific helper T-cell subsets were also examined over a 6 month period. A significant decline was seen in the CD4+/DC29+, CD4+/DC45R+, and overall CD4+ subsets which were not seen in AZT treated patients. A significant increase in the CD4+/CD29+ memory T-cell subset, which is responsible for response to recall antigens and is capable of Upsilon interferon secretion, was noted in the AZT-treated group. Author

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ANALYSIS OF DISEASE PROGRESSION FROM CLINICAL OBSERVATIONS OF US AIR FORCE ACTIVE DUTY MEMBERS INFECTED WITH THE HUMAN IMMUNODEFICIENCY VIRUS: DISTRIBUTION OF AIDS SURVIVAL TIME FROM INTERVAL CENSORED OBSERVATIONS

JORGE ARAGON, MARY WESTON (Aerospace Medical Research Labs., Brooks AFB, TX.), and RONALD WARNER (Aerospace Medical Research Labs., Brooks AFB, TX.) *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992

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A nonparametric estimator of the Acquired Immunodeficiency Syndrome (AIDS) survival time (after developing AIDS) is computed for the AIDS data set from the US Air Force (USAF). Survival times are unobservable. They are censored by the screening mechanism. The Armstrong Laboratory's Epidemiologic Research Division maintains data on over 940 active duty US Air Force (USAF) individuals who tested positive for Human Immunodeficiency Virus (HIV) antibodies. Many have been clinically evaluated six times since 1986. The HIV-positive individual is classified in seven stages of the disease complex as time

progresses. Exact times of transition from one stage to the next are unknown. It is known that transition occurred between two consecutive evaluations. The aim of this study is to analyze distributions of the times that individuals spend in each stage of the HIV disease complex. We discuss methods used to obtain nonparametric estimators of the distributions of times that individuals spend in stage 6. Finally, we hope to model the median time spent in each stage of the disease. This, along with incidence and separation data, will allow us to predict the impact of HIV disease on USAF individual and medical care systems. Author

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RELATING COGNITIVE FUNCTION TO MILITARY AVIATOR PERFORMANCE IN EARLY HIV INFECTION
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There has been controversy about whether cognitive changes occur in early human immunodeficiency virus (HIV) disease. In those studies reporting cognitive changes, findings are typically subclinical, and their relationship to daily and/or occupational functioning has not been addressed. The potential effects of changes may vary as a function of occupational demands. This is germane to military performance, where occupational demands cover a wide spectrum of complexity. In particular, such effects are important to consider in the many cognitively-demanding specialties associated aviation. Ways in which possible HIV-related military performance decrements in aviators may be measured empirically are explored. First, studies from Walter Reed Army Medical Center (WRAMC), which have shown cognitive changes in early HIV disease, are described. This is followed by a summary of presentations and discussions at a November, 1990 conference, entitled, HIV and Military Performance: Assessment Methodologies, held at WRAMC. The third section describes a program of research, which is developing measures to detect cognitive difficulties in civilian aviators. The application of measures from this research to research on HIV is discussed. Finally, a research program being developed to examine the possible impact of HIV-related cognitive changes on military aviator performance is presented. Author

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NEUROPSYCHIATRIC MORBIDITY IN EARLY HIV DISEASE: IMPLICATIONS FOR MILITARY OCCUPATIONAL FUNCTION
GEORGE R. BROWN, JAMES R. RUNDELL (Walter Reed Army Medical Center, Washington, DC.), SUSAN E. MCMANIS (Air Force Medical Center, Lackland AFB, TX.), SARAH N. KENDALL, and RICHARD A. JENKINS (Walter Reed Army Medical Center, Washington, DC.) *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 14 p (SEE N93-11283 02-52) Apr. 1992
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The Military Medical Consortium for Applied Retroviral Research's (MMCARR) Behavioral Medicine Human Immunodeficiency Virus (HIV) Research component is conducting a tri-service, comprehensive, and longitudinal research study in military HIV-infected personnel at all stages of infection. Identification of neuropsychiatric and psychosocial outcomes and their determinants will help the military minimize the impact of the HIV epidemic on military readiness and function. Neuropsychiatric and psychosocial findings are among the most common complications seen in early HIV Disease and among the most likely to have an adverse impact on military readiness and function. The study has demonstrated that the average HIV-infected service-person experiences at least transient military occupational difficulty following notification of HIV status. More than 15 percent at any given time have levels of clinical or subclinical anxiety or depression that are referrable for mental health intervention. Ten percent of study subjects have a current major mood disorder and 5 percent have a psychoactive substance use disorder. Finally, 17 percent of study subjects have experienced serious suicidal ideation or behaviors at least once since notificaiton of seropositivity. Fortunately, however, data also indicate at least partial effectiveness of current primary, secondary, and tertiary preventive efforts. Only about 1 percent of Air Force HIV-infected persons are discharged for psychiatric reasons prior to eventual medical discharge. Further, a large majority of active-duty patients demonstrate solid military occupational and social performance. Though military HIV neurobehavioral research is still in progress, preliminary data identify social support and pre-HIV psychiatric predisposition as important factors associated with current neuropsychiatric status. Author

N93-11300# World Health Organization, Geneva (Switzerland). Div. of Communicable Disease.
COMMUNICABLE DISEASES: A MAJOR BURDEN OF MORBIDITY AND MORTALITY
G. TORRIGIANI *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992
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Communicable diseases, complicated by malnutrition and other adverse socioeconomic factors, continue in the present decade to contribute greatly to the unacceptably high levels of morbidity, mortality, and disability, particularly in the under-five age group, in all developing countries. It is estimated that five million deaths occur per year from diseases which can be prevented by vaccines available today, and that another five million people are being crippled, blinded, or mentally retarded as a result of the same diseases. Some of the most important communicable diseases, with their mortality rate, are reported. Some of the topics discussed include sexually transmitted diseases, disease control, chemotherapy, and environment management. Author

N93-11301# Aerospace Medical Research Labs., Brooks AFB, TX. Epidemiology Div.
SUSCEPTIBILITY IN USAF RECRUITS TO VACCINE PREVENTABLE DISEASES
WILLIAM F. CLARDY *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992
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Because of increasing incidence of mumps in a cohort of under immunized young adults and the concern about the impact of this disease on the USAF recruit population, two studies were undertaken. These studies took a retrospective look at the following: mumps in the active duty population; a cost analysis of immunizing all or only susceptible individuals; the actual antibody response in a group of two hundred and seventy-six recruits in basic training; the demographic patterns of susceptibility; and the types of previous immunication documentation. The conclusions were that the numbers of new mumps cases per year did not justify immunizing all recruits or screening for mumps antibodies. Author

N93-11302# Sclavo Research Center, Rome (Italy). Office of the Surgeon General of the Army.
ABSENCE OF PROTECTIVE IMMUNITY AGAINST DIPHTHERIA IN A LARGE PROPORTION OF YOUNG ADULTS
R. RAPPUOLI, A. PODDA, F. GIOVANNONI, L. NENCIONI, M. PERAGALLO, and P. FRANCOLINI *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 2 p (SEE N93-11283 02-52) Apr. 1992
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The schedule of vaccination which is recommended worldwide for diphtheria, tetanus, and other diseases provides good immunity during childhood. However, little attention has been paid to keep an effective immunity in adults. We have collected sera from 334 recruits of the Italian Army and tested them for the presence of protective immunity against diphtheria and tetanus. In vivo neutralization assays were performed on rabbits and mice and the values below 1/100 IU/ml were considered negative. Of the recruits, 22.9 percent were negative for diphtheria, while only 5.3 percent of them did not have protective immunity against tetanus. This finding shows that a large proportion of the Italian young adults are susceptible to diphtheria, and this could be dangerous if they travel to sites where this disease is still endemic, or if they come into contact with people coming from such areas. A booster vaccination of young adults against diphtheria should enter in the common practice in order to avoid this risk. In order to reduce the side effects which are often associated with diphtheria vaccination in adults, we have developed a vaccine which contains a highly purified nontoxic mutant of diphtheria toxin. This vaccine

is combined with tetanus toxoid and can be routinely used as a booster in adults. Author

N93-11303# Divisione Aerea Studi Ricerche e Sperimentazioni, Pratica di Mare (Italy).

DRAMATIC REDUCTION OF MENINGOCOCCAL MENINGITIS AMONG MILITARY RECRUITS IN ITALY AFTER INTRODUCTION OF SPECIFIC VACCINATION

R. BISELLI, A. FATTOROSSI, P. M. MATRICARDI, R. NISINI, T. STROFFOLINI, and R. DAMELIO (Istituto Superiore di Sanita, Rome, Italy) *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 5 p (SEE N93-11283 02-52) Apr. 1992

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Meningococcal meningitis still represents a serious infectious disease with a mortality rate that can be as high as 10 percent even in developed countries. Military recruits are generally a high risk group for meningococcal disease, with a reported incidence of 4 to 10 times greater than that of the general population. In Italy the results of the National Meningitis Surveillance Program showed a high attack rate of the disease among recruits in 1985 as well as in 1986, with 92 and 95 percent of the cases, respectively, caused by serogroup C and thus preventable. These findings constituted the motivating factors leading to the authorities' decision to make vaccination against meningococcal disease mandatory for recruits starting from January 1987. After almost 5 years from the introduction of meningococcal vaccination, we present a summary of the epidemiological and immunological effects of the vaccination. From the epidemiological point of view we have observed a dramatic reduction of the prevalence of the disease. In 1987, that is the year in which we had 150,000 unvaccinated and 150,000 vaccinated recruits, the protective efficacy was 91.2 percent. From the immunological point of view, vaccination is highly effective, as seroconversion against polysaccharide (PS) A and C is 84 and 91 percent, respectively. The spectrotypic analysis of the sera before and after vaccination shows that the type of response is mainly oligoclonal, like the majority of the responses to PS's, and the antibodies induced by sole PS are not qualitatively different from the antibodies induced by natural immunization. In addition, the efficacy is not modified by environmental factors like hypoxia, as demonstrated during permanence at 16,174 feet for 20 days. In conclusion, the anti-meningococcal PSA and PSC vaccine can be looked at as a very safe and effective method in controlling the spread of the disease in military recruits since: (1) its efficacy is very high, considering approximately 90 percent of the subjects develop a protective response; (2) it is safe; and (3) it has proven to provide satisfactory immunological response even under unfavorable conditions, like hypobaric hypoxia. Author

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IMMUNIZATION OF PERSONNEL TRAVELING TO A DESTINATION IN TROPICAL COUNTRIES: FRENCH POSITION [IMMUNISATION DU PERSONNEL NAVIGANT A DESTINATION DES PAYS TROPICAUX: POSITION FRANCAISE]

F. DIDELOT, C. P. GIUDICELLI, J. P. GOURBAT, J. P. BURLATON, G. NEDELEC, and A. SEIGNEURIC *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992 In FRENCH

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The possibility of infectious risks incurred during sojourns in tropical zones justifies preliminary prevention. Aside from obligatory measures, it is important to discern recommended and other desirable actions. The obligatory measures essentially concern antimalarial vaccination for those personnel whose travel brings them into the intertropical zones of Africa and America. The partial and limited efficacity of the anticholera vaccination has practically justified its abandonment. The recommended measures include vaccinations against tetanus, diphtheria, poliomyelitis, (BCG) and typhoid. Obligatory in France for all children, except for the latter, these vaccinations must be replaced by boosters for all adults. Well tolerated, the new vaccine against typhoid (polyosidic, purified Vi antigen) merits being systematically employed. Other immunizations are desirable: vaccinations against meningococcic meningitis (serogroups A and C) in the young adult and against viral hepatitis B and injection of gammaglobulins for the prevention of hepatitis A virus. Finally, the high tolerance for anti-rabies vaccine leads to counseling the generalization of its use, due to the possible risk of a supply default at an opportune moment. Contradictions are restated and a vaccinal calendar is proposed. Aside from oral forms of vaccines against cholera and against typhoid, future perspectives concern vaccines against viral hepatitis A and against Japanese encephalitis. These are directed against the major risks, those such as malaria and AIDS unfortunately appear, even today, to be aleatory. Author

N93-11305# Divisione Aerea Studi Ricerche e Sperimentazioni, Pratica di Mare (Italy).

CLINICAL AND IMMUNOLOGICAL RESPONSE TO VACCINATION WITH PARENTERAL OR ORAL VACCINES IN TWO GROUPS OF 30 RECRUITS

ROBERTO NISINI, ROBERTO BISELLI, PAOLO M. MATRICARDI, ANDREA FATTOROSSI, and RAFFAELE DAMELIO *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 4 p (SEE N93-11283 02-52) Apr. 1992

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The clinical and immunological responses to typhoid vaccination with parenteral and oral vaccines in two groups of 30 adult male subjects were studied. Specific anti-Salmonella typhi cell-mediated immunity and total or specific anti-lipopolysaccharide fecal immunoglobulin (Ig) A titers in vaccinated subjects were monitored. Cellular antibacterial activity was significantly increased only in orally vaccinated subjects. Serum arming activity and inhibition experiments suggested an IgA-dependent cellular cytotoxicity in those orally vaccinated. In these subjects, a total and anti-lipopolysaccharide fecal IgA increase was observed lasting up to 8 months after completion of vaccination schedule. In parenteral vaccinated subjects, an early onset transitory increase of IgM rheumatoid factor was observed. Oral vaccine was well tolerated and free of side effects, whereas 65 percent of parenterally vaccinated subjects reported side effects such as fever, headache, malaise, and local tenderness in the injection site. Author

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STUDIES OF SAFETY, INFECTIVITY, AND IMMUNOGENICITY OF A NEW TEMPERATURE SENSITIVE (TS) 51-1 STRAIN OF S. TYPHI AS A NEW LIVE ORAL TYPHOID FEVER VACCINE CANDIDATE

J. A. BELLANTI, B. J. ZELIGS, S. VETRO, Y.-H. PUNG, S. LUCCIOLI, M. J. MALAVASIC, A. M. HOOKE, T. R. UBERTINI, R. VANNI, and L. NENCIONI *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 6 p (SEE N93-11283 02-52) Apr. 1992 Prepared in cooperation with Sclavo S.p.A., Sienna, Italy

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This report describes the results of a phase 1 study evaluating the safety, infectivity, and immunogenicity of a new live oral S. typhi ts 51-1 typhoid fever vaccine in the human. Three normal males subjects ranging in age from 20 to 40 years received 3 oral doses of S. typhi ts 51-1, each dose containing 10(exp 9) organisms. Prior to and following immunization each subject was carefully monitored by clinical and laboratory parameters over a two week period during which serial specimens of blood and stool were analyzed for the presence of the organism. Blood specimens were also obtained for the determination of serum antibody and cell-mediated immune responses and stool filtrates were analyzed for the development of coproantibody. The results of these studies indicate that: (1) the vaccine is well tolerated with no clinical or laboratory evidence of adverse reactions; (2) ts 51-1 was detected in only one stool specimen from one volunteer; the organism recovered displayed characteristics of the ts 51-1 vaccine strain; (3) although no significant humoral or cell-mediated lymphocytotoxic immune responses were detected in the blood, coproantibody was detected in stool specimens from all of the 3 immunized subjects and IgA-armed ADCC activity was detected in 2 of 3 subjects. These studies indicate that S. typhi ts 51-1 may be a suitable strain for the development of an improved oral typhoid fever vaccine. Studies are in progress to determine optimal methods of vaccine delivery preparatory to larger phase 2 studies of efficacy. Author

N93-11307# Zurich Univ. (Switzerland). Div. of Epidemiology and Prevention of Communicable Diseases.

RECENT LESSONS ON THE SAFETY AND EFFECTIVENESS OF MALARIA CHEMOPROPHYLAXIS IN A NON-IMMUNE POPULATION

R. STEFFEN *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 4 p (SEE N93-11283 02-52) Apr. 1992
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To assess adverse events (AE) and the effectiveness of malaria chemoprophylaxis in short term travelers to East Africa, two similar follow-up studies were conducted, the second of which is on-going. Pooled data of both studies are presented, in which all passengers returning from Kenya by British, German, or Swiss charter flights were distributed a questionnaire aboard and a second one three months later. Any report of documented malaria or of a hospitalization for adverse events was investigated with the physician. So far, 98,650 travelers have completed at least one questionnaire. AE were reported by 22.3 percent of 30,871 having used mefloquine (MQ), by 19.9 percent of 5,342 having used chloroquine (CQ) 300 mg base/week, by 22.2 percent of 7,930 having used Q 600 mg base/week, by 29.4 percent of 1,114 having used amodiaquine (AQ), by 1.63 percent of 24,532 having used sulfadoxine/pyrimethamine (SP), and by 26.1 percent of 6,851 having used CQ plus proguanil (PG). Dizziness was more frequent with MQ than with other agents. Twenty hospitalizations were attributed to AE: seven occurred after prophylaxis with CQ (including 2 cases of psychosis), four were attributed to SP (2 fatal), and five to AC (2 fatal). Just two were attributed to MQ: one each for psychosis and one for seizures in a known epileptic, one additional case with seizures was not hospitalized. Prophylactic effectiveness was 94 percent (95 percent C.I. 85-96) for MQ, 84 percent (77-90) for SP, 74 percent (48-88) for CQ+PG, and 30-54 percent for CQ in various dosages. In conclusion, mefloquine appears to be highly efficacious for malaria prophylaxis in areas with widely distributed chloroquine resistant P. falciparum. Tolerance seems to be comparable to the one of chloroquine; thus, the contra-indication of the use of mefloquine in pilots will have to be reconsidered. Author

N93-11308# Walter Reed Army Medical Center, Washington, DC. Dept. of Immunology.

USE OF NOVEL ADJUVANTS AND DELIVERY SYSTEMS TO IMPROVE THE HUMORAL AND CELLULAR IMMUNE RESPONSE TO MALARIA VACCINE CANDIDATE ANTIGENS

D. M. GORDON *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 4 p (SEE N93-11283 02-52) Apr. 1992
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The immune effector mechanisms responsible for the solid protection against malaria, as demonstrated by immunization with radiation attenuated sporozoites, are poorly understood. An effective malaria vaccine must induce a well orchestrated combination of humoral and cellular immune responses directed against critical parasite antigens/epitopes expressed during different stages of the parasites complicated life-cycle. Currently, licensed human vaccine adjuvants, such as alum, may improve antibody production but are poor stimulators of cellular effector mechanisms, while potent cellular stimulants such as Freund's adjuvant are too reactogenic for human use. Over the last five years, we have systematically evaluated several methods of antigen presentation to include chemical conjugation to bacterial carrier proteins, emulsification in 'Freund's-like' preparations, and incorporation into liposomes. This work has resulted in the production of safe, potent vaccine delivery systems capable of targeting multiple antigenic determinants to the host's immune system. Further advances in malaria vaccine development now depends on the identification of appropriate parasite epitopes for inclusion in a multicomponent-multistage vaccine. Author

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CYTOKINES AS VACCINE ADJUVANTS: INTERLEUKIN 1 AND ITS SYNTHETIC PEPTIDE 163-171

ALDO TAGLIABUE *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 5 p (SEE N93-11283 02-52) Apr. 1992
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The possibility of preventing infectious diseases by employing efficacious vaccine is rapidly growing as the consequence of the new technologies in recombinant DNA and protein chemistry. However, the increasing number of synthetic and recombinant antigens further stresses the importance of the role of appropriate adjuvants to ensure the maximal vaccine activity and the protection of all vaccines. Several approaches can be applied to develop safe and effective agents capable of enhancing specific immune responses which can then protect the host from the pathogen. Among others, the direct use as adjuvant of those cytokines which are induced in animals by the classical Freund adjuvants has recently become a matter of investigation. In particular, interleukin 1 (IL-1) has been shown to possess adjuvant activity for a variety of infectious and tumor antigens. However, the numerous side effects associated to the proinflammatory action of IL-1 represent a serious disadvantage for its use as a vaccine adjuvant. Therefore, it was of great interest that the observation of a nonapeptide contained in the IL-1beta sequence (residues 163-171 corresponding to the sequence VQGEESNDK) is devoid of all the proinflammatory activities but maintains the immunostimulating activity of the whole IL-1beta. Thus, 163-171 peptide was successfully employed in animals to potentiate the specific immune response against T helper-dependent cellular antigens, T helper-independent polysaccharidic antigens and recombinant, as well as synthetic antigenic preparations derived from human pathogens. Furthermore, IL-1 and 163-171 peptide were successfully used in tumor vaccines in experimental systems. Therefore, it can be concluded that 163-171 peptide is potentially a good candidate as vaccine adjuvant for human use. Author

N93-11310# World Health Organization, Geneva (Switzerland). Microbiology and Immunology Support Services.

FUTURE APPROACHES TO VACCINE DEVELOPMENT SINGLE-DOSE VACCINES USING CONTROLLED-RELEASE DELIVERY SYSTEMS

M. T. AGUADO *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 4 p (SEE N93-11283 02-52) Apr. 1992
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The development of new vaccines, both more efficacious and easier to deliver, has become an area of research that can certainly benefit from recent technical developments. In particular, the conversion of multiple-dose vaccines into single-dose vaccines may represent an important advance which should lead to improved vaccination coverage, as well as to a reduction in vaccination costs. Taking these considerations into account, one of the main goals of our program has become the development of a strategy to convert multiple dose vaccines to single-dose vaccines with the same or increased effectiveness. The initial priority of this project was to develop a single-dose tetanus vaccine, as one of the most urgent needs of the Expanded Program on Immunization to control neonatal tetanus. The use of controlled-release systems, already applied to deliver a whole array of drugs and hormones both in cattle and man, appears to be one way of accomplishing our goal. Among these systems, polymeric particles have been widely used for injectables. They can be classified into two main groups: the reservoir type, with material in solution in the cavity formed by a polymeric membrane; and the monolithic type, with materials evenly dispersed throughout the polymeric matrix. Indeed, the first type is usually known as microcapsules and the second as microspheres. Microspheres seems to be preferred to microcapsules because of the better control of drug or vaccine liberation. At present, the pre-clinical results obtained seem to point in the direction of the successful development of single-dose controlled-release vaccines. Author

N93-11311# Georgetown Univ., Washington, DC. Dept. of Pediatrics.

EPIDEMIOLOGIC VIEW OF ALLERGIC DISEASES IN NORTH AMERICA: IMPLICATIONS FOR AEROSPACE MEDICINE

J. A. BELLANTI *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992

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The allergic disorders comprise a heterogeneous group of diseases which involve the respiratory tract (e.g., allergic rhinitis and asthma), the skin (e.g., atopic eczema), and the gastrointestinal tract (e.g., allergic gastroenteritis, food allergy) and which afflict 50 million Americans. The respiratory allergic diseases affect major segments of the population (15 to 17 percent) who may be recruited as aircraft personnel; therefore, these diseases pose particular risk to flying safety or personnel either directly, or indirectly as a consequence of their disease or of the adverse effects of medications now used in the treatment of these disorders. Moreover, recent evidence is now accumulating to suggest that other environmental factors encountered in aerospace operations, e.g., gravity, oxygen, and stress, may also contribute to the immunologic responses involved in and responsible for clinical manifestations of these allergic disorders. A thorough knowledge of these allergic diseases and reactions associated with therapy are, therefore, essential for proper screening of personnel prior to entry into the aerospace field. Moreover, principles of allergic therapy should be applied to existing trained personnel and combined with a knowledge of careful use of medications which are least likely to be associated with performance decrement. The availability of new medications which have minimal adverse effects, e.g., non-sedating antihistaminic drugs, are addressing some of the problems associated with these issues. Author

N93-11312# Divisione Aerea Studi Ricerche e Sperimentazioni, Pratica di Mare (Italy).

THE SCREENING OF INHALANT ALLERGIC DISEASES IN THE SELECTION OF CANDIDATES FOR AIRCRAFT PILOTING

P. M. MATRICARDI, R. NISINI, R. BISELLI, L. URBANI, C. DEANGELIS, G. PETRELLI, and R. DAMELIO *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 5 p (SEE N93-11283 02-52) Apr. 1992

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The validity of Phadiatop CAP as a tool in the mass screening for inhalant allergies was investigated. Two-hundred and seventy of 1815 Italian recruits were classified as allergics to inhalant allergens on the basis of history, physical examination, SPT for inhalants, and/or RAST for the seven most common aeroallergens in Italy. Phadiatop was positive in six-hundred and twenty-three (34.3 percent) subjects: in 265/270 allergics and in 357 subjects which had never experienced allergic symptoms; the vast majority of these subjects were also positive to STP and/or RAST. The level of Phadiatop reactivity was lower in this group with respect to the allergic one. In a subgroup of 98 subjects, bronchial hyperresponsiveness was also examined. A very high percentage (85 percent) of the subjects with bronchial hyperresponsiveness were also positive to Phadiatop, suggesting that atopy is one of the major etiologic factors of bronchial hyperreactivity in our population sample. We conclude that Phadiatop CAP is extremely useful in the screening of inhalant allergies in candidates to aircraft piloting. Author

N93-11313# Red Cross Hospital, The Hague (Netherlands) Dept. of Respiratory Medicine.

PHADIATOP: A SCREENING TEST FOR INHALANT ALLERGY

A. M. J. WEVER *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992

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The Phadiatop test, a new in vitro test for inhalant allergy, was evaluated in relation to a panel of seven RAST tests with the common inhalant allergens in the Netherlands, and in comparison with the PRIST for total immunoglobulin E (IgE) determinations, in two populations: one in which the prevalence of inhalant allergy was expected to be high and one in which it was expected to be low. The Phadiatop was classified positive or negative according to percentage binding, total IgE was considered elevated at values greater than or equal to 200, greater than or equal to 150, and greater than or equal to 100 kU/l at ages 12-14, 15-16, and 17 years and over respectively. The RAST panel as reference was considered positive when at least on RAST result was class 2 or more. From the predictive values (which depend on the prevalence of the disease in the population) and the accuracies of the Phadiatop and the PRIST for the RAST, it can be concluded that the Phadiatop is a highly efficient test, much more so that the PRIST, in correctly classifying atopic and non-atopic subjects as judged by the reference RAST panel. Author

N93-11314# Navy Hospital, La Spezia (Italy).

IN VIVO AND IN VITRO DIAGNOSIS OF ALLERGIC RESPIRATORY DISEASE DURING SCREENING PROCEDURES IN THE ITALIAN NAVY: COMPARATIVE EVALUATION OF A RECENT QUANTITATIVE AUTOMATIZED ENZYME IMMUNOASSAY METHOD TO DOSE SPECIFIC IGE

G. ANZALONE, M. DELTRECCO, A. VIZZACCARO, and A. CORSICO *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 7 p (SEE N93-11283 02-52) Apr. 1992

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The observation of a large number of young allergic patients gave us the possibility to acquire crucial information on the epidemiology, the aetiology, and the pathogenesis of respiratory allergies and particularly that of bronchial asthma. The diagnostic protocol used accomplished in a satisfactory way the proposed tasks to screen allergic conscripts and to clinically study already in service patients. Our evaluation of the recently introduced immunoassay ABBOTT-MATRIX confirmed its characteristics of specificity and reproducibility. It also demonstrated to be an easy to use 'in vitro' system with very poor requirements of intervention by the operator. We emphasize the need to routinarly introduce 'in vitro' research of allergies for the preliminary screening of the candidates to the Military Academies, the schools for P. Officers, and to special categories with an expensive training and high risk, like pilots or divers. Author

N93-11315# Defence and Civil Inst. of Environmental Medicine, North York (Ontario). Central Medical Board.

ASTHMA IN AIRCREW: ASSESSMENT, TREATMENT AND DISPOSITION

GARY W. GRAY *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 4 p (SEE N93-11283 02-52) Apr. 1992

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Asthma represents a spectrum of increased airway reactivity from mildly increased responsiveness through to severe life-threatening bronchospasm. Rational recommendations for treatment and aeromedical disposition require a careful assessment of bronchial reactivity through correlation of the clinical findings with results of pulmonary function testing including an objective measure of airway reactivity. Airway challenge testing with methacholine allows a safe, objective assessment of airway reactivity. In the Canadian Forces, aircrew candidates with a history of wheezing, recurrent cough or bronchitis in childhood, or abnormal screening PFT's are further screened with an airway challenge test. Applicants with a PC20 less than 4 mg/ml are disqualified from pilot selection, and less than 2 mg/ml from other aircrew. Trained aircrew who develop wheezing are assessed with full pulmonary function testing including a methacholine challenge test. Those with objectively confirmed mild bronchial hyper-reactivity requiring no treatment or controlled by inhaled anti-inflammatory agents (corticosteroids, sodium cromoglycate, nedocromial sodium) are returned to flying in other than fast jets where even minor small airway instability may worsen ventilation-perfusion mismatch caused by +Gz. Author

N93-11316# Belgian Air Force, Brussels (Belgium). Medical Centre of Aerospace Medicine.

ALLERGY SCREENING AND FOLLOW-UP IN STUDENT PILOTS OF THE BELGIAN AIR FORCE (BAF)

N. MORTIER, P. VANDENBOSCH, and C. VANCUTSEM *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992

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The different methods used in the Medical Center of Aerospace Medicine, Brussels (Med C Aerospace) to detect allergy in pilot applicants, are discussed. During the period 1987 through 1989,

the Total immunoglobuline E (IgE) levels were also determined at the start of pilot training. The aim was to assess if Total IgE could be used as an additional selection criterion. We conclude that it is not useful to determine the total IgE in the selection of pilot candidates. The existing investigations and examination methods are sufficient to detect allergy. Author

N93-11317# Hellenic Air Force General Hospital, Athens (Greece). Div. of Allergy.
ALLERGIC AND NONALLERGIC RHINITIS IN GREEK PILOTS
C. GRIGOREAS, D. PAPPAS, A. AGELIDIS, and E. CHIMONAS *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992
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In order to study the Allergic Rhinitis (AR) and Nonallergic Rhinitis (NAR) in Greek pilots, we examined 144 Greek male pilots, aged from 23 to 50 years, with symptoms of chronic rhinitis. The diagnosis was based on: (1) detailed history; (2) physical examination; (3) Skin Prick Tests (SPT) on common aeroallergens (positive SPT greater than 3 mm wheal); and (4) nasal secretions for assessment of eosinophilia (positive eosinophilia 20 percent eosinophils in nasal smears). Also, we measured serum total immunoglobuline E (IgE) (IV/ml) by the Paper-Radioimmunosorbent Test (PRIST) method and expressed as geometric mean value. We excluded patients suffering from chronic rhinitis (infections, mechanical-anatomic, drug-induced, sinusitis, and metabolic states) and bronchial asthma. Eighty-six patients (59.7 percent) had Seasonal Allergic Rhinitis (SAR), 30 patients (20.8 percent) had Perennial Allergic Rhinitis (PAR), 22 patients (15.3 percent) had Vasomotor Rhinitis (VR), and 6 patients (4.2 percent) had Nonallergic Rhinitis with Eosinophilia (NARE). One patient with PAR and 2 patients with NARE possessed nasal polyps. The frequency of major positive SPT in the SAR group was: (1) grasses (80.2 percent), (2) olive (69.7 percent), (3) parietaria (50 percent); and in the PAR group was: (1) House dust (100 percent), (2) mite D. Farinae (93.3 percent), (3) mite D. Pteronyssinus (90 percent). The levels of IgE among the four groups were 174.6 IV/ml in the VR group and 39.2 IV/ml in the NARE group. It is concluded, that in Greek pilots: (1) AR (SAR and PAR) was more frequent than NAR (VR and NARE); (2) the major aeroallergens responsible were different in patients with AR, since pollens predominated in the SAR group and house dust-mites in the PAR group; (3) patients with NARE had a high prevalence of nasal polyps; and (4) IgE levels were higher in patients with AR (SAR and PAR) than in patients with NAR (VR and NARE). Author

N93-11318# Hellenic Air Force General Hospital, Athens (Greece). Center of Aviation Medicine.
CORRELATION OF SERUM ALPHA SUB 1 ANTITRYPSIN WITH CIGARETTE SMOKING AND PULMONARY FUNCTION STATUS IN GREEK PILOTS, FOR A TEN YEAR PERIOD
J. PALERMOS, K. KYRIAKOS, S. MICHALOPOULOU, CH. DASKALOPOULOS, and A. BITSAKTSIS *In* AGARD, Allergic, Immunological and Infectious Disease Problems in Aerospace Medicine 3 p (SEE N93-11283 02-52) Apr. 1992
(AGARD-CP-518) Copyright Avail: CASI HC A01/MF A03

Quantitative and mainly qualitative aberration of the alpha sub 1 Antitrypsin (a sub 1 AT) a major constituent of the human antielastase screen, is strictly associated with the development of lung emphysema. Certain factors like cigarette smoking and environmental pollution may contribute to that. In this study, we have correlated cigarette smoking with the serum a sub 1 AT concentration as well with the trend of predicted values of Forced Vital Capacity (FVC) and 1st Second Forced Expiratory Volume (FEV sub 1) over a ten year period. The study population consisted of 113 randomly selected male pilots, of the Greek Airforce, being in flight duties grouped into nonsmokers (n = 49, age x = 36.3) and effective smokers (n = 64, age x = 38.4) smoking for more than ten years. Serum a sub 1 AT level was 176 plus or minus 36 md/gl (mean plus or minus SD) and 199 plus or minus 32 mg/dl for nonsmokers and smokers, respectively (p less than 0.001). Serum a sub 1 AT level for Greek male population was 190 plus or minus 35 mg/dl and the frequency of individuals with intermediate serum a sub 1 AT level was 2.7 percent. Recent and past (ten years ago recorded) FVC and FEV sub 1 predicted values were measured. This data suggest that: (1) cigarette smoking affects serum a sub 1 AT level; (2) intermediate serum a sub 1 AT level cannot be employed as a predictive criterion for flight personnel's pulmonary status; (3) ten years of cigarette smoking worsens the pulmonary function status significantly; and (4) extra physical exercise improves it. Author

N93-15824# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
OPERATIONAL USE OF CONTACT LENSES BY MILITARY AIRCREW [L'UTILISATION OPERATIONNELLE DES LENTILLES DE CONTACT]
E. ALNAES, ed. Oct. 1992 36 p
(AGARD-AG-334; ISBN-92-835-0690-1; AD-A258675) Copyright Avail: CASI HC A03/MF A01

The text discusses the operational requirements of military personnel relative to the use of contact lenses (CL) and particular emphasis is given to the experience of those NATO air forces that currently have aircrew flying with contact lenses. Topics such as lens optical performance, user compliance, and a definition of adequate eye-care supervision are highlighted. The text seeks to identify the critical factors to be taken into account when the decision is made to permit the use of contact lenses by military aircrew, and weights medical considerations and military field conditions, in this regard. Finally, specific military aeromedical conditions in modern aircraft are discussed, with emphasis on the advantages and disadvantages of CL visual correction. Based on extensive deliberations in the group, WG 16 offers a detailed list of recommendations for the use of CL by military aircrews. These recommendations will also be useful for military medical authorities supervising visual correction guidelines for non-flying personnel. Author

N93-19663# Queens Medical Centre, Nottingham (England). Dept. of Orthopaedic and Accident Surgery.
CAN INJURY SCORING TECHNIQUES PROVIDE ADDITIONAL INFORMATION FOR CRASH INVESTIGATORS?
J. M. ROWLES, W. A. WALLACE, and D. J. ANTON (Royal Aerospace Establishment, Farnborough (England).) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 10 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

The Abbreviated Injury Score (AIS) and Injury Severity Score were calculated for all passengers and crew of the M1 Kegworth aircraft crash. Regional scores were significantly higher in nonsurvivors than survivors of the impact. Mortality and ISSs were found to correlate with the structural damage sustained by the aircraft. The use of injury scoring has highlighted variations in the severity of injuries sustained by occupants involved in an impact aircrash. This information has demonstrated that other factors in addition to the force of the impact were involved in the causation of injury, such as structural integrity, attempts by occupants to protect adjoining passengers, being struck by loose objects and rear facing seats. Author

N93-19664# Queens Medical Centre, Nottingham (England). Dept. of Orthopaedic and Accident Surgery.
IS AXIAL LOADING A PRIMARY MECHANISM OF INJURY TO THE LOWER LIMB IN AN IMPACT AIRCRAFT ACCIDENT?
J. M. ROWLES, P. BROWNSON, W. A. WALLACE, and D. J. ANTON (Royal Aerospace Establishment, Farnborough (England).) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992
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Following the crash of a Boeing 737-400 aircraft on the M1 motorway near Kegworth, England, on 8 January 1989, it became apparent that a large number of pelvic and lower limb injuries had been sustained by the survivors. Had there been a fire this would have severely hindered the ability of the occupants to escape. The mechanism of pelvic and lower limb injuries in impact accidents has been related to failing of the limbs and axial loading of the femur. The validity of axial loading of the femur as a primary mechanism of femoral fracture in an impact aircraft accident is questioned. Two methods of study have been used to investigate the impact biomechanics of the pelvis and lower limb: clinical review and impact testing using anthropomorphic dummies. Our study suggests that in the presence of intact occupant protection systems, bending of the femur over the front spar of passenger seats is the primary mechanism of causation of femoral fractures.

Occupant protection systems designed for civil aircraft should be modified to accommodate loading of the femur over the front of the seat. Author

N93-19683# German Air Force, Fuerstenfeldbruk (Germany).
EFFECTS OF MEDIUM BLOOD ALCOHOL LEVELS ON PILOTS' PERFORMANCE IN THE SEA KING SIMULATOR MK-41
M. KRAEMER *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 3 p (SEE N93-19653 06-03) Sep. 1992
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A number of 20 military pilots drank certain amounts of alcohol until the blood alcohol concentrations reached a level of about 0.8 o/oo. After that they had to fly an IFR mission using the flight simulator for 2 1/2 hours. They were told to perform the complete program of navigation and flight operations and also communications with, for example, air traffic control (ATC). During the simulated flight programmed technical failures occurred concerning the instruments and the engine. The reactions of pilots and the cause were registered. The results were obtained by summarizing false reactions. Significant differences in the number of wrong reactions due to alcohol consumption were registered. Author

N93-19694# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
FIRES ON BOARD AIRCRAFT: TOXICOLOGICAL RISK IN FLIGHT [INCENDIES A BORD DES AERONEFS: RISQUE TOXICOLOGIQUE EN VOL]
M. KERGUELEN, M. MIGNET, and J. M. JOUANY *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 12 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH
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At the time of fires on board aircraft, intoxication by the products of the thermolysis of the materials used in the installation of the cabin represents a major risk. To evaluate the toxic risk of fires on board aircraft in flight, it is necessary to take into account not only the ventilation but also the pressure of the cabin, which can vary between 1000 and 750, even 700 hPa. An original model fire was developed, making it possible to study, under ventilation conditions representative of an aircraft, the influence of the pressure on the thermolysis of various materials. Thermolysis was considered on physiochemical and toxicological levels, the mouse being chosen as the experimental animal. The study showed that the toxic risk varies considerably according to the material considered. In addition, under these experimental conditions, the barometric pressure drop from 1000 to 700 hPa hardly modified the physicochemical characteristics of the thermolysis of the majority of studied materials. On the other hand this pressure drop generally generated a very significant increase in toxicity of the generated gas mixture, in which carbon monoxide and/or hydrocyanic acid have a dominant share. Author

N93-19695# German Air Force, Fuerstenfeldbruk (Germany). Aviation Pathology Group.
TOXICOLOGICAL INVESTIGATIONS OF FLIGHT ACCIDETNS: FINDINGS AND METHODS
G. POWITZ *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 7 p (SEE N93-19653 06-03) Sep. 1992
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After accidents with fume in the cockpit a characteristic profile of pyrolysis products is gaschromatographically often detectable in the blood. This profile we have to distinguish from an inhalation of fuel or from a fasting blood. The sensitivity was improved. If carbonyl compounds are supposed in the biological materials, we identify them by the reaction with semicarbazide in the head space bottles of the gaschromatograph. From about 5 percent CO-Hb, we determine photometrically the cyanide level. After a fatal crash over the sea bromide-concentrations were found in the examination materials, which exceeded clearly the physiological area. All previous results with essential longer immersion-times in sea-water told against a contingent uptake of bromide from the sea. Experiments with animal and human lungs demonstrated, that we have to calculate with such an enrichment in biological materials yet. With this knowledge, a second pilot in an analogous case could be cleared from the suspicion of having abused bromine containing sedatives, too. In estimating from a corpse, we ascertained gaschromatographically distinct higher values than with the enzymatic method. Further examinations showed that, caused by bacterial putrefaction, an alcohol formation occurred during the sample preparation. Any alcohol concentrations in the elder literature have to be regarded under a new aspect after that. In some investigations of dead pilots we identified hypnotics. In one case it succeeded to determine the time of intake with the more unspecific thin-layer chromatography instead of mass spectrometry. According to that, the extraction procedures became modified. The different used extraction methods for the single drug categories will be compared. Author

N93-19696# German Air Force, Fuerstenfeldbruk (Germany). Aerospace Pathology and Toxicology.
27 YEARS ARMED FORCES AEROSPACE PATHOLOGY AND TOXICOLOGY IN THE FEDERAL REPUBLIC OF GERMANY: DEVELOPMENT, CURRENT STATUS, TRENDS AND CHALLENGES
B. MAYR, G. APEL, and M. KRAEMER *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 3 p (SEE N93-19653 06-03) Sep. 1992
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The west German armed forces Aerospace Pathology and Toxicology was founded in April 1964 as a division of the German Airforce Institute of Aerospace Medicine. Prof. S. Krefft was assigned the development of this division in a time of increasing accident rates due to the so-called 'F-104 G Starfighter crisis'. Krefft developed the concept of a mobile, airborne investigation and autopsy team with centralized laboratories for identification, histopathology and toxicology at Furstenfeldbruck AFB, near Munich. Though the doctors of the autopsy team normally are addressed as pathologists, they are in fact forensic pathologists, thereby meeting the requirements of German law. Trends in accidents and incidents are evaluated and discussed with respect to future developments. New methods and techniques are presented such as DNA-based identification. Author

N93-19697# German Air Force, Fuerstenfeldbruk (Germany). Aerospace Pathology and Toxicology.
SIGNIFICANCE OF HISTOLOGICAL POSTMORTEM FINDINGS IN PILOTS KILLED IN MILITARY AND CIVIL AIRCRAFT ACCIDENTS IN GERMANY (WEST): A 25-YEAR-REVIEW
M. KRAEMER and U. STOCKER *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 5 p (SEE N93-19653 06-03) Sep. 1992
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The Division of Aerospace Pathology and Toxicology ('Flugunfallmedizin') at the German Air Force Aerospace Medical Institute was founded in 1964 by Col. Prof. Krefft and is since then located at Furstenfeldbruck AFB near Munich. The Division is engaged in the medical and medico-legal part of all fatal accident - most non fatal accident - and incident investigations concerning German military aircraft (Airforce, Navy and Army). The Division performs also some civilian medical accident investigations for the Federal Aviation Administration ('FUS, Flugunfall Untersuchungsstelle beim Luftfahrt Bundesamt'). The autopsy files of the period 1 January 1965 up to 31 December 1990 were reviewed. In 231 civilian and military crashes a total of 455 autopsies was performed, resulting in 385 valid autopsy reports of killed pilots including a histopathological examination. Histopathological findings were coded and stored in a data base of an IBM compatible computer. In those cases with positive histopathological findings in the files the tissue was reexamined. 36 cases showed severe histopathological alterations. 21 of these might be considered to have reduced physical and/or mental performance and thus have affected the capability of flight safety. A selection of ten cases is used to discuss problems of accident causality in case of positive histopathological findings. The value and validity of findings especially in those cases of a high degree of tissue destruction is demonstrated. In aircraft accident investigations autopsy and histopathological examination must - on the basis of nearly 5 percent positive histopathological findings - be regarded as mandatory. Author

N93-19698# Hellenic Air Force General Hospital, Athens (Greece).

AIRCRAFT ACCIDENT INJURIES IN THE HELLENIC AIR FORCE IN THE LAST 20 YEARS

ODYSSEAS PAXINOS *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 4 p (SEE N93-19653 06-03) Sep. 1992

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Military flying is a dangerous activity and safety is a major concern. Post accident pathology is an essential tool of determining the cause of death of the pilot, types of injuries, possible physiological problems that contributed to the accident and finally, possible solutions to improve safety. The aircrew injuries of 151 Class-A accidents, of the Hellenic Air Force, in the last 20 years is presented. Accidents were divided, according the aircraft type, in three groups: Jet Aircraft Accidents, Fixed Wing Props Accidents and Helicopter Accidents. In the Jet Aircraft group, a subdivision was made in three more subgroups: Non ejection attempted, successful ejection and unsuccessful ejection. In all groups the type and location of injuries was recorded, and the results were discussed. An attempt was made to give possible solutions. Injury data bank of aircraft accidents can be very useful in improving accident investigation techniques and safety and more data must be recorded. Author

N93-19707# Paris V Univ. (France).

STUDY OF THE SPECTRUM OF POWER OF CARDIAC RHYTHM DURING TASKS RELATING TO THE SAFETY OF THE CONTROL OF AN APPARATUS [ETUDE DU SPECTRE DE PUISSANCE DU RYTHME CARDIAQUE AU COURS DE TACHES RELATIVES A LA SECURITE DE LA CONDUITE DE L'APPAREIL]

J. P. FOUILLOT, M. BENAOUDIA, P. CABON, A. BENHALLA, and A. COBLENTZ *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 1 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH

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The relaxation of attention to this subject increases the probability of the occurrence of minor errors of which the absence of detection and the accumulation are likely to lead to an incident. Mulder, Vicente, Morey and other authors showed the interest of the study of the spectrum of the power of cardiac rhythm, and more particularly of the frequency band 0.05 - 0.15 Hz in the evaluation of the mental effort of the subject. We have previously shown the existence of a correspondence between measurements of cardiac variability in the temporal field, and the subjective evaluation of the workload of the pilot. This is primarily a mental workload whose main components are the pressure of time, stress and mental effort. We continued this study of the cardiac rhythm of the pilot, in the frequential field, and development of a program to analyze the power spectrum of the heart rate taking into account the limits of studying a discrete signal. The recording of the heart rate is carried out by means of an ambulatory monitoring system and is associated with synchronous observation of the activity of the subject. This method was applied to measurements carried out during psychophysiological tests in the laboratory and during real situations of the piloting of various aircraft. The results obtained show the sensitivity of the spectral energy of the cardiac rhythm in the frequency band 0.05 - 0.15 Hz, to the mental effort of the subject. However, the spectral energy in this frequency band is not correlated with the difficulty of the task, nor with the performance. Certain subjects slacken their mental effort when the difficulty of the task appears excessive to them, others maintain it or increase it without improving their performance. The increase or absence of reduction in the spectral energy of the cardiac rhythm when facing a task of increased difficulty, or during tasks relating to the safety of the piloting of the aircraft, could constitute a factor which leads to error and increases the probability of incident or accident. Author

N93-19708# Regie Renault, Nanterre (France).

CONTRIBUTION OF THE ANALYSIS OF OCULAR ACTIVITY (COMPLEMENTARY TO THE ELECTROENCEPHALOGRAPHIC ANALYSIS) TO THE DETECTION OF LOW VIGILANCE IN INSTANCES OF PILOTING A VEHICLE [CONTRIBUTION DE L'ANALYSE DE L'ACTIVITE OCULAIRE (COMPLEMENTAIRE DE L'ANALYSE ELECTROENCEPHALOGRAPHIQUE) A LA DETECTION DES BAISSES DE VIGILANCE DANS LES TACHES DE PILOTAGE DE VEHICULE]

C. TARRIERE, S. PLANQUE (Association pour la Recherche Interessant la Medicine du Travail, Paris, France), C. CHABANON (Regie RENAULT, Aubevoye, France), P. ARTAUD (Association pour la Recherche Interessant la Medicine du Travail, Paris, France), and C. LAVERGNE (Association pour la Recherche Interessant la Medicine du Travail, Paris, France) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH

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The Department of Environmental Sciences of RENAULT studies a system of detection of the drops in vigilance of the driver. Installed in the vehicle, this has as its role the prevention of any deterioration in the state of vigilance of the driver. The principle is based on the analysis in real time of the movements which the driver imposes on his wheel. The design of such a system requires, in a study phase, the knowledge at any moment of the level of vigilance of the subject from physiological signals, in order then to determine the parameters of the Flying Angle signal which will be ready to substitute itself there in order to distinguish two states of vigilance. We present here a method allowing the definition of a physiological reference of the level of vigilance of the driver, based on the approach complementary to electroencephalography (EEG), electrooculography (EOG) and on behavioral analysis by video imagery. The trend analysis of the oculographic diagrams significantly improves the early detection of hypo-vigilance. Thanks to the knowledge of this physiological reference, we now have the results obtained on the Flying Angle signal in terms of detection of hypo-vigilance. Author

N93-19710# Gulhane Skeri Tip Akademisi, Eskisehir (Turkey). Aerospace Medical Center.

EFFECTIVENESS OF BIRTHDATE BIORHYTHM THEORY ON FLIGHT ACCIDENTS

MUZAFFER CETINGUC, UMIT SARYKAYALAR (Gulhane Skeri Tip Akademisi, Ankara, Turkey), and KEMAL SAVASAN (Gulhane Skeri Tip Akademisi, Ankara, Turkey) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 6 p (SEE N93-19653 06-03) Sep. 1992

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Birthdate Biorhythm Theory presents a daily guideline to people about the time of their highest and lowest performance. The theory is that it is possible to estimate in which days physical, intellectual or emotional success or failure would happen. The results reached by this investigation, in short, is that popular birthdate biorhythm theory is not capable of explaining the aircraft accidents. Ideal minimum level can be reached by objective and cautious inspections in order to decrease the accidents. The most important conditions in this is to consider the reasons and precautions from scientific perspective. It may be interesting to approach by simple method requiring scientific discussion but one must not fall in its traps. I.I.C.

N93-32249# Service de Medecine Aeronautique, Versailles (France).

LIPODYSTROPHIES IN THE FRENCH MILITARY FLIGHT CREW [LES DYSLIPIDEMIES DANS LE PERSONNEL NAVIGANT MILITAIRE FRANCAIS]

A. SEIGNEURIC, J. P. BURLATON, J. DEROCHE, R. RICHARD, and A. BOUSSIF *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 5 p (SEE N93-32240 12-54) Mar. 1993 In FRENCH

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Disorders of the lipid metabolism in the French flight crew were evaluated beginning with a population having aeronautical expertise who were hospitalized between 1980 and 1989. An anomaly: -pure hypertriglyceridemy (hyper TGD) - mixed lipodystrophy - isolated hypercholesterolemy (hyper CT), were recognized in 52.3% of the cases (483/923). A hyper CT with an elevated risk was confirmed in 34.8% of the cases (294/923). It

is in the group of controllers that this anomaly is th most frequent, with 40% of the subjects affected (50/120), whereas approximately 30% of the subjects are affected in the various groups of pilots as well as among the mechanics and navigators. The follow-up carried out for 177 flying personnel in an average period of two and a half years showed the existence of a cardiovascular attack for 12% of the subjects. Therapeutic treatment (diet +/- medication) was effective in 45% of the cases. The decrease in the numbers for cholesterol, the triglycerides, and for a multifactoral risk factor is established at around 10%. Transl. by FLS

N93-32250# Hellenic Air Force Aeromedical Center, Athens (Greece).
LIPIDEMIC PROFILE OF HELLENIC AIRFORCE OFFICERS
J. PALERMOS, A. KITSOU, S. MICHALOPOULOU, and K. KYRIAKOS *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 4 p (SEE N93-32240 12-54) Mar. 1993
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To gain a better insight into the lipidemic profile of our personnel, the serum concentration of total lipids, total cholesterol, triglycerides, phospholipids, high and low density cholesterol, A-1 and B apolipoproteins were measured chemically in 324 healthy ground officers. Additionally, the LDL cholesterol was estimated using the Friedewald's formula LDLfc = chol-HDLc-(trig/5). The population under study, randomly selected, consisted of male, ground officers in active duty serving in the Hellenic Airforce with similar socio-economic status, without any history of coronary heart disease or diabetes mellitus and not receiving any medication. They were grouped into three groups (n= 108) of 31-35, 36-40, and 41-45 years old. A statistically significant increase in the blood concentration of total cholesterol, triglycerides, LDL cholesterol, and apolipoproteinB were found in the 36-40 age group. A significant percentage of individuals in every age group had blood lipid concentrations (cholesterol 41.7 percent, LDL-cholesterol 51.9 percent, triglycerides 7.1 percent, apolipoprotein A-1 43.8 percent) exceeding the desirable levels that prevent an increased risk of a coronary heart disease. Estimated LDLfc values were higher than the measured ones, but from regression analysis, stronger relationship between LDLfc and total cholesterol was found. No correlation between HDLc and total cholesterol was found. Finally our results suggest that: (1) a high percentage of our ground personnel has blood lipid concentrations (principally chol, LDLc, ap-A1) exceeding the levels that prevent an increased risk of coronary heart disease (CHD); (2) people aged over 40 seem to be sufficiently aware of the risk of high blood lipid concentrations and this awareness has to be extended toward younger ages; (3) certain lipids (phos, HDLc, apo-A1) do not vary among the age groups studied and are possibly not discriminatory markers for the screening of lipidemic profile. Estimated LDLfc, though higher than the measured LDLc, showed stronger relationship with total cholesterol and under restrictions can be considered as trustworthy index of the lipidemic profile. Author (revised)

N93-32251# Royal Air Force Central Medical Establishment, London (England).
BLOOD LIPIDS IN AIRCREW RECRUITS AND IN RAF AVIATORS
D. H. HULL *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 8 p (SEE N93-32240 12-54) Mar. 1993
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Blood cholesterol is a major indicator of cardiovascular risk, mainly from coronary artery disease. Blood lipid elevations are a common cause for referral of RAF aircrew for specialist assessment. The need for investigation, treatment (dietary, drugs), repeated counseling and indefinite follow-up constitutes a significant commitment. Blood lipids were measured in fasting male subjects from two groups; young recruits provisionally accepted for RAF flying training, and trained RAF aircrew. Mean blood cholesterols (SD's) were 4.65 (0.89) mmol/l (180 (34) mgm/dl) in recruits and 5.5 (1.14) mmol/l (213 (44) mgm/dl) in trained aircrew. Corresponding figures for triglycerides were 1.13 (0.56) mmol/l (100 (50) mgm/dl) in recruits and 1.46 (0.86) mmol/l (129 (76) mgm/dl). All differences between groups were significant (p is less than .001). Lipid levels were correlated with age in both groups. Blood lipid levels in recruits were in general satisfactory; the main purpose of measurement remains the detection of the occasional individual with a familial hyperlipidaemia. Blood cholesterols in trained aircrew, though lower than the average for British men, were above desirable limits in 50 percent of all aircrew tested. Ten percent were in the band requiring clinical care and 2 percent might require drug treatment. A program to reduce cardiovascular risk in RAF personnel will include dietary, exercise, and other measures. Author (revised)

N93-32252# Italian Air Force Pratica di Mare, Rome.
CARDIOVASCULAR RISK FACTORS IN AN ITALIAN AIR FORCE POPULATION: PRELIMINARY REPORT
S. FARRACE, L. SAKARA, L. URBANI, and C. DEANGELIS *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 4 p (SEE N93-32240 12-54) Mar. 1993
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Two hundred male subjects from an Italian Air Force AFB were admitted after informed consent to an epidemiological study on the diffusion of cardiovascular risk factors. They were divided in two groups: group A (n=150; aged 37.7 plus or minus 10.7 yr.) was personnel mainly employed in logistic and administrative activities, group B (n=50; aged 35.2 plus or minus 7.8) were pilots regularly performing flight activity. Each subject underwent a clinical examination, height and weight, resting ECG and blood pressure recording, as well as a 20 ml blood sampling. Measurement of total cholesterol, HDL cholesterol, glucose, uric acid, APO-A, APO-B, and Lp(a) lipoprotein concentration was carried out in each subject. Data showed that while lipid values and mean arterial pressure (MAP) levels are significantly lower in group B (p is less than 0.05) as compared to group A, APO A/B ratio and Lp(a) lipoprotein concentration are significantly higher (p is less than 0.05). These findings may suggest that, despite a lipid profile and mean MAP level within the physiological range and independently from these parameters, it may be recognizable in the pilot group a trend towards atherosclerosis development which needs to be further investigated. Author (revised)

N93-32253# Centro de Instruccion de Medicina Aeroespatial, Madrid (Spain).
CARDIOVASCULAR RISK FACTORS (CVRF) IN SPANISH PILOTS WITH CORONARY ARTERY DISEASE DEMONSTRATED BY ANGIOGRAPHIC STUDIES
M. A. GOMEZ-MARINO, C. ALONSO, and F. RIOS *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 10 p (SEE N93-32240 12-54) Mar. 1993
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During the years 1987-1991, 32 Spanish pilots with ages between 39 and 56 years (47.34 +/- 4.81) had demonstrated coronary obstructive lesions by means of coronary angiography. Each case was studied investigating separately, the following cardiovascular risk factors (CVRF) - cigarette smoking, hypercholesterolemia, hypertrigliceridemia, diabetes, arterial hypertension, obesity, and coronary disease family history. It was found that CVRF were present in all the Spanish pilots with proved coronary artery disease. 87.5 percent were heavy smokers and 68.5 percent had high levels of plasma cholesterol. The smoking habit was the most important single CVRF, even more than cholesterol high levels, but they may be relationed with the very high number of cigarettes smoked (33.2 +/- 11.5 for a period of 24.7 +/- 6.3 years). Other CVRF were of little value if not associated to hypercholesterolemia or smoking habit. A proper control of CVRF it should be a priority over the pilot population in order to increase flight safety and the efficiency of the air operations. Author (revised)

N93-32254# German Air Force, Fuerstenfeldbruk (Germany). Aviation Medicine Div.
RESULTS AND MANAGEMENT OF PATHOLOGICAL LIPOPROTEIN CONCENTRATIONS AND OTHER CARDIOVASCULAR RISK FACTORS IN MILITARY PILOTS OF THE GERMAN FEDERAL ARMED FORCES
ERICH ROEDIG *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 8 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

As a result of research findings during the past years, the level and type of circulating lipoprotein concentrations have become a subject of focal interest. It is now well established that high cholesterol levels are related to the extent and severity of arteriosclerotic heart disease. Before this background, the aeromedical physician is called upon to act now, considering the increased psychic and physical demands the new weapon systems

will impose on the aviator. In a 4-year survey the lipoprotein concentrations of German military pilots were examined under standardized conditions, the results being evaluated in a statistical program at the German Air Force Institute of Aviation Medicine. Additional risk factors influencing the cardiovascular system are also mentioned. Cholesterol level is greater than 220 mg/dl and HDL cholesterol is less than 35 mg/dl are considered as pathological. This is true in 52.4 percent of German military pilots older than 41 years. In 1992, of all pilots (N=4563) examined, 37.2 percent show cholesterol levels greater than 220 mg/dl while 25.1 percent have a tot. chol./HDL-chol. ratio is greater than 6.0. These results differ from those in the years before. Therefore, besides dietary and physical fitness programs, a regime to reduce pathological lipoprotein concentrations will also be introduced. It is mandatory from an aeromedical point of view that risk factors and disorders of the cardiovascular system be detected by medical flying fitness examination. This particularly applies to silent cardiac ischemia. Author (revised)

N94-23313# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
CARDIOPULMONARY ASPECTS IN AEROSPACE MEDICINE [LES ASPECTS CARDIOPULMONAIRES EN MEDECINE AEROSPATIALE]
Oct. 1993 74 p Lectures held in Lisbon, Portugal, 25-26 Oct. 1993, in Athens, Greece, 1-2 Nov. 1993, in Ankara, Turkey, 4-5 Nov. 1993, and in Brussels, Belgium, 8-9 Nov. 1993
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This Lecture Series will update the information presented in the 1987 AGARD Short course on the Cardiopulmonary Aspects of Aerospace Medicine, and will be of primary relevance to military internists and cardiologists with an interest in aviation medicine, and to military Flight Surgeons. Topics to be discussed will include the following: screening to asymptomatic coronary artery disease in an aircrew population; the aeromedical disposition of aviators with coronary disease; the utility of screening aircrew candidates with echocardiography and echocardiographic findings in trained aircrew; etc. The Lecture Series is designed to be interactive rather than strictly didactic to encourage discussion of problems particular to participating NATO countries. For individual titles, see N94-23314 through N94-23328.

N94-23314# Defence and Civil Inst. of Environmental Medicine, Toronto (Ontario). Medical Assessment Section.
CARDIOVASCULAR AND PULMONARY DISEASE IN NATO AIRCREW: AN OVERVIEW
GARY W. GRAY *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 6 p (SEE N94-23313 06-52) Oct. 1993
(AGARD-LS-189) Copyright Avail: CASI HC A02/MF A01

In 1987, the AGARD Aeromedical Panel (AMP) sponsored a Short Course on the Cardiopulmonary Aspects of Aerospace Medicine. The aim of the course was to disseminate current information about the aeromedical implications of cardiac and pulmonary conditions to NATO Flight Surgeons. At the time of the first course, it was proposed that an update course be run every five to six years to keep NATO Flight Surgeons abreast of current developments in aviation cardiology and pulmonology. Since the 1987 Lecture Series, there have been a number of new developments in aviation cardiology. The purpose of this Lecture Series is to disseminate this information. Author (revised)

N94-23315# Air Force Systems Command, Brooks AFB, TX. Clinical Sciences Div.
SCREENING FOR ASYMPTOMATIC CORONARY HEART DISEASE
WILLIAM B. KRUYER *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 5 p (SEE N94-23313 06-52) Oct. 1993
(AGARD-LS-189) Copyright Avail: CASI HC A01/MF A01

Predicting the presence of coronary heart disease in an asymptomatic population is a very difficult task. Because of the possible sudden and incapacitating presentation of coronary heart disease and its common occurrence in industrialized nations, screening for this disorder is an important aeromedical concern. Nonsignificant disease can lead to coronary events and is also likely to progress to significant disease. Also, lifestyle changes and other interventions may affect the progress of insignificant disease. Screening efforts in the military aviator population should therefore be aimed at detecting any measurable degree of disease. This review will discuss problems inherent to screening an asymptomatic population, different screening tests, and risk stratified approaches to screening for coronary heart disease. Author (revised)

N94-23316# Air Force Systems Command, Brooks AFB, TX. Clinical Sciences Div.
AEROMEDICAL DISPOSITION FOR CORONARY ARTERY DISEASE
P. V. CELIO *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 6 p (SEE N94-23313 06-52) Oct. 1993
(AGARD-LS-189) Copyright Avail: CASI HC A02/MF A01

Coronary artery disease continues to be a significant concern in aerospace medicine. Coronary disease is a major cause of deaths and sudden incapacitation for males in the flying age population. When coronary disease is found in an aviator, the benefits of his remaining on flying duties must be weighed against his risk of an incapacitating event. The following chapter reviews the probability of a cardiac event in populations of varying degrees of coronary disease including patients following myocardial infarction, angioplasty, and coronary artery bypass surgery. The U.S. Air Force (USAF) experience and recommendation for flying waivers will also be discussed. Author

N94-23317# Air Force Systems Command, Brooks AFB, TX. Clinical Sciences Div.
PRIMARY PREVENTION OF CORONARY HEART DISEASE
WILLIAM B. KRUYER *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 6 p (SEE N94-23313 06-52) Oct. 1993
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The primary prevention of coronary heart disease is a very prominent and vigorously discussed topic in the medical literature, especially in the area of appropriate lipid profile management. Secondary preventive efforts in patients with known disease seem to be clearly beneficial, but the literature and opinions vary considerably regarding primary preventive efforts and how the existing data should be applied to other patient population subgroups. Studies demonstrating regression of coronary artery atherosclerotic lesions seem to lend support to the validity of primary prevention. This topic is of major interest to the military aerospace medicine practitioner. Classic risk factors which are most applicable to the military aviator include lipid profile, smoking, and regular exercise. These factors will be discussed with pertinent information from the literature with the intent of providing a better understanding of the issues and a reasonable approach to this problem. Author (revised)

N94-23318# Air Force Systems Command, Brooks AFB, TX. Clinical Sciences Div.
AEROMEDICAL DISPOSITION OF ARRHYTHMIAS AND ELECTROCARDIOGRAPHIC FINDINGS IN AIRCREW
P. V. CELIO *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 9 p (SEE N94-23313 06-52) Oct. 1993
(AGARD-LS-189) Copyright Avail: CASI HC A02/MF A01

Screening asymptomatic individuals for occult cardiac disease continues to be a difficult task. One of the standard screening procedures continues to be electrocardiography. Electrocardiography is neither a sensitive nor specific tool in identifying heart disease but continues to offer useful information. Interpretation of these studies for aeromedical purposes requires an appreciation for certain differences between a standard clinical population from which the significance of most ECG findings were obtained and the asymptomatic, generally healthy aviator population. The United States Air Force Central Electrocardiographic Library is the repository for all electrocardiograms obtained on Air Force aviators. This facility was established in 1957 in order to review electrocardiograms performed on Air Force aviators to determine the significance of electrocardiographic findings in asymptomatic individuals and to provide consultative services to local flight surgeons as well as the Surgeon General. The following sections discuss the major classes of electrocardiographic findings, their significance, and additional evaluations required by the USAF. Author (revised)

N94-23319# Defence and Civil Inst. of Environmental Medicine, Toronto (Ontario). Medical Assessment Section.
ECHOCARDIOGRAPHIC SCREENING OF AIRCREW CANDIDATES
GARY GRAY *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 2 p (SEE N94-23313 06-52) Oct. 1993
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Military pilot training is expensive for all NATO countries, and screening techniques which detect medical conditions at selection which might later result in grounding or operational restriction of trained pilots are generally cost-effective. Although a careful physical examination and electrocardiogram will detect most disqualifying conditions, there are a number of structural cardiac abnormalities which may be missed by these standard screening measures. These include the following: mitral valve prolapse; bicuspid aortic valve; hypertrophic cardiomyopathy; left ventricular hypertrophy; diastolic dysfunction; regurgitant valves--aortic, mitral, tricuspid, and pulmonic; significant stenosis--aortic, pulmonic, and mitral; and congenital lesions, e.g Ebstein's anomaly. Only four of thirteen NATO aeromedical agencies polled by questionnaire reported that an echo cardiogram is included in the routine initial screening of air crew candidates. The detection of disqualifying or limiting cardiac abnormalities in trained air crew is a clear argument in favor of screening, but it is really the incidence of such abnormalities detected in air crew candidates which determines the cost effectiveness of the procedure. Author (revised)

N94-23320# Air Force Systems Command, Brooks AFB, TX. Clinical Sciences Div.
ECHOCARDIOGRAPHIC FINDINGS IN TRAINED AIRCREW: THE EFFECT OF +GZ ON CARDIAC STRUCTURE (WORKING GROUP 18)
P. V. CELIO *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 2 p (SEE N94-23313 06-52) Oct. 1993
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During the AGARD conference 'Medical Selection and Physiologic Training of Future Fighter Aircrew' in Apr. 1985, a paper was presented on echocardiography in Mirage 2000 pilots. In this study, 32 Mirage 2000 pilots and 34 transport pilots underwent echocardiography in order to evaluate the possibility of cardiac changes occurring because of high performance flying. The authors found a statistically significant increase in left atrial size and left ventricular septal thickness. They also felt that there was a very significant difference in right ventricular dimensions. The mean right ventricular size for the transport pilots and the Mirage pilots was 13.265 mm and 16.750 mm, respectively. They felt that 8 of the Mirage 2000 pilots had dilated right ventriclcs whereas only one of the transport pilots had an enlarged right ventricle. Although the cause of this apparent difference could not be determined by the study, the presence of right ventricular dilatation in high performance pilots raised a significant occupational concern among the NATO countries. Although this may simply be an artifact of the small sample size or a result of the inherent difficulty in obtaining right ventricular dimensions, the possibility that this represented a true occupational hazard was seriously considered. In order to determine the significance of this finding, a larger study was undertaken. The intention of this study is to perform a large cross-sectional study comparing the echocardiographic findings obtained on pilots flying high sustained G aircraft with non high sustained G pilots (tanker, bomber, transport, helicopter pilots, etc.). Author (revised)

N94-23321# Royal Air Force, London (England). Central Medical Establishment.
LEFT VENTRICULAR HYPERTROPHY AND ATHLETE'S HEART
DAVID H. HULL *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 4 p (SEE N94-23313 06-52) Oct. 1993
(AGARD-LS-189) Copyright Avail: CASI HC A01/MF A01

Left ventricular hypertrophy (LVH) means literally, overgrowth of the left side of the heart. However the term is generally limited to an abnormal increase in the mass of the left ventricular heart muscle. In pathological terms, this means an increase in the size of the cardiac myocytes as opposed to hyperplasia, an increase in their number. In common parlance, any thickening of the left ventricular wall tends to be described as LVH; this is incorrect where the thickening is due to increase in the size or number of cells other than myocytes, such as fibroblasts, or to abnormal deposits, e.g., amyloid. LVH may be present with normal wall thickness in an enlarged ventricle, for example in volume overload. In health, left ventricular mass is directly related to stature and to body weight, and it increases steadily with age so a single standard (maximum) left ventricular wall thickness for all ages, both sexes, and all bodily configurations must be inappropriate. However, normative standards incorporating these sources of variability are rarely employed. Author (revised)

N94-23322# Royal Air Force, London (England). Central Medical Establishment.
AORTIC VALVE DISEASE
DAVID H. HULL *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 2 p (SEE N94-23313 06-52) Oct. 1993
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The aortic valve, like the pulmonary valve, forms early in foetal cardiac development soon after the fusion of the 2 bulbar ridges which thus become a septum dividing the primitive bulbus cordis into the aortic and pulmonary trunks. Two cusps of each valve arise from the fused ridges, whilst a third cusp is formed from accessory ridges in each outflow tract. The normal arrangement is of symmetrical semilunar 3-cusped valves in the aorta and the pulmonary trunk, but variations are common. A bicuspid aortic valve is present in 1-2 percent of adults; a unicuspid or quadricuspid valve is much rarer. Bicuspid valves are 4 times commoner in men than in women. Lesser degrees of asymmetry are so common as to be the rule; in one series, only 16 percent of normal aortic valves were perfectly symmetrical in the sense that all 3 cusps were within 5 percent of each others dimensions; in 33 percent of valves, all 3 cusps differed from each other by more than this amount. The significance of these minor degrees of asymmetry, particularly with regard to the later development of aortic valve disease, is unknown. Congenital aortic valve abnormalities are common associations of other types of congenital heart disease, notably of coarctation of the aorta and ventricular septal defect. Aortic valve lesions are asymptomatic in most young people; because of this, and of male preponderance, congenital aortic valve disease is quite common in applicants for flying training; as abnormal physical signs are often trivial or absent, acceptance into air crew training is probably the rule, and the abnormality is recognized only later. Author (revised)

N94-23323# Air Force Systems Command, Brooks AFB, TX. Clinical Sciences Div.
AEROMEDICAL IMPLICATIONS OF MITRAL VALVE PROLAPSE
P. V. CELIO *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 3 p (SEE N94-23313 06-52) Oct. 1993
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Mitral valve prolapse (MVP) is the most common cardiac valve disorder in the general adult population. Although the prevalence has been estimated at between 4 percent and 21 percent, the true prevalence is dependent upon the specific population evaluated and the diagnostic criteria applied. For the adult male population of aircrew age, the prevalence is probably between 4 to 7 percent. Although the prognosis of individuals with MVP is generally good, rare complications do occur which include sudden death, infective endocarditis, stroke, transient ischemic attacks, and progressive mitral regurgitation. The following discussion will review the diagnostic criteria as well as the probable risk of each reported complication. Author (revised)

N94-23324# Royal Air Force, London (England). Central Medical Establishment.
CHRONIC OBSTRUCTIVE PULMONARY DISEASE
DAVID H. HULL *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 4 p (SEE N94-23313 06-52) Oct. 1993
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Chronic Obstructive Pulmonary Disease (COPD) remains a common cause of illness and death in many Western countries and is an increasing problem in developing nations. Although COPD is declining slowly in the UK, it still causes 15,000 deaths annually and is responsible for 10 percent of all working days lost through illness. This is despite improved working conditions, reduced atmospheric pollution, and decreased tobacco consumption. In the USA, COPD is the fifth most common cause of death, causing 57,000 deaths per year. It is estimated that 81.5 percent of this toll is due to cigarette smoking. Clinically apparent disease is largely

confined to middle-aged and elderly people, but many young cigarette smokers can be shown to have early evidence of airways disease if adequately investigated. Two main types of COPD are seen, chronic bronchitis and emphysema, though patients may show features of both disorders. Chronic bronchitis is defined as the production of mucoid sputum on most days for at least 3 months during 2 consecutive years. Recurrent respiratory infection is increasingly common as the disease progresses. Stopping smoking may, especially early in the disease, arrest or slow its progression. Otherwise deterioration is relentless. Apart from variable rhonchi, physical signs are often slight till the onset of cor pulmonale, that is failure secondary to the broncho-pulmonary disease. Finger-clubbing, raised venous pressure, fluid retention, evidence of right ventricular hypertrophy, hypercarbia with respiratory acidosis and raised intracranial pressure, and eventually hypoxaemia are the main features; despite remissions cor pulmonale is usually fatal within a few years. Author (revised)

N94-23325# Royal Air Force, London (England). Central Medicine Establishment.
SARCOIDOSIS AND THE AVIATOR
DAVID H. HULL *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 3 p (SEE N94-23313 06-52) Oct. 1993
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Sarcoidosis is a chronic granulomatous disease of unknown aetiology. It is of particular importance in clinical aviation practice, for a number of reasons. Although it is a world-wide disease, it appears to be much more prevalent in the populations of developed countries. It is common in young adults; in Europe, more men than women being affected, but possibly the reverse in the USA. The onset may be acute and incapacitating, for example with florid erythema nodosum and acute arthropathy. Other cases are a symptomatic and may be detected only by special tests, e.g., screening chest x-ray, ECG, or blood biochemistry. Though often apparently confined to the thorax, sarcoidosis is typically a multi-system disease with involvement, often silent, of many organs: the skin, eyes, liver, spleen, lymphnodes, bone, central nervous, and cardiovascular systems. Hypercalcaemia is quite a common feature but causes symptoms only when potentially dangerous blood calcium levels are attained. No curative treatment is known, but moderate, severe or progressive disease usually leads to steroid treatment which may have to be prolonged and given in high doses. Cardiac involvement is often inapparent, but can be present with incapacitating arrhythmias, complete heart block with Stokes-Adams attacks, or sudden death. A table summarizes the aspects of main aeromedical concern. Author (revised)

N94-23326# Royal Air Force, London (England). Central Medical Establishment.
SPONTANEOUS PNEUMOTHORAX, CYSTS AND BULLAE
DAVID H. HULL *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 2 p (SEE N94-23313 06-52) Oct. 1993
(AGARD-LS-189) Copyright Avail: CASI HC A01/MF A01

Spontaneous pneumothorax is defined as the presence of air in the pleural cavity without apparent cause. Pulmonary conditions such as tuberculosis or cancer may cause spontaneous pneumothorax, but are excessively rare in aeromedical practice. The usual victims are apparently healthy young men, often in the third decade of life, very often tall and of lean, asthenic build. The chest x-ray may be normal before or after the illness, but may show sub-pleural blebs or small cysts, usually at the lung apex; the rupture of a bleb creates a broncho-pleural communication and the natural elastic lung recoil plus negative pleural pressure draws air into the pleural space. Consequent pulmonary collapse and contraction will narrow and perhaps seal the defect, which usually closes spontaneously in a few days. However the air may take several weeks to reabsorb fully, especially if the pneumothorax is large, so that some form of evacuation of the air, e.g., by underwater seal or flutter valve, is usually desirable for any but the smallest pneumothoraces. The disease is disproportionately important in aeromedical practice, for various reasons. Author (revised)

N94-23327# Defence and Civil Inst. of Environmental Medicine, Toronto (Ontario). Medical Assessment Section.
ASTHMA IN AIRCREW
GARY GRAY *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 3 p (SEE N94-23313 06-52) Oct. 1993
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Asthma is a disease characterized by airway inflammation and increased bronchial reactivity. Symptoms, which characteristically are variable, include wheezing, shortness of breath, chest tightness, and cough with sputum. In the past, attention was focused on the airway hyper-reactivity with bronchospasm and wheezing, and treatment was directed towards bronchodilation as first line therapy. In recent years the central role of airway inflammation in the pathogenesis of asthma has gained increasing recognition. Airway inflammation is present in even mild asthmatics, and the treatment of asthma has evolved towards more aggressive management of the underlying inflammatory response as a key element in control. Author (revised)

N94-23328# Royal Air Force, London (England). Central Medical Establishment.
ARTERIAL HYPERTENSION AND THE AVIATOR
DAVID H. HULL *In* AGARD, Cardiopulmonary Aspects in Aerospace Medicine 7 p (SEE N94-23313 06-52) Oct. 1993
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Arterial hypertension is of great importance in the practice of clinical aviation medicine, mainly because of its prominence as a major risk factor for coronary artery disease and other disabling cardiovascular diseases and because it is so common. Timely recognition of early or mild hypertension should facilitate appropriate intervention which will prevent complications and enable the air crewman to continue his career, hopefully, to normal retirement age. The consequent health benefits and fiscal advantages, both to the individual and to the air forces and airlines of the world, are obvious and substantial Author (revised)

N94-28421# Robert Gordon's Inst. of Tech., Aberdeen (Scotland).
MEDICAL SUPPORT FOR BRITISH OPERATIONS IN THE ANTARCTIC
S. R. K. COLESHAW and J. N. NORMAN *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 5 p (SEE N94-28420 08-51) Oct. 1993
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This paper presents an overview of the work undertaken and support given to members of the British Antarctic Survey, discussing some of the environmental hazards to which the personnel are exposed. Derived from text

N94-28423# Royal Air Force, Farnborough (England). Inst. of Aviation Medicine.
PREDICTION OF SURVIVAL TIMES ON LAND IN A COLD CLIMATE
G. MAIDMENT *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 12 p (SEE N94-28420 08-51) Oct. 1993
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Eight subjects were exposed to three different combinations of air temperature and wind speed for two hours in a climatic chamber. Changes in core temperature, surface temperatures and heat flux, and metabolic rate were recorded during the exposure. The results obtained were compared with the predictions derived from a sophisticated computer model of human thermoregulation and heat exchange. Conclusions about the factors responsible for the rate of body cooling in air and the causes of the wide range of variability observed are discussed. The problems of predicting survival times on land for a diverse population are considered, and possible solutions are suggested. Author (revised)

N94-28425# Survival Systems Ltd., Dartmouth (Nova Scotia).
EFFECT OF SEASICKNESS ON AIRCREW STUDENT SURVIVOR ABILITY AFTER DITCHING IN COLD WATER
ALBERT BOHEMIER *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 7 p (SEE N94-28420 08-51) Oct. 1993
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It is suggested that immediate, effective biochemical seasickness treatment for ditched aircrew does not exist, in addition

to the fact that the severity of the problem in cold water survival is not currently documented, and therefore not sufficiently recognized. Author (revised)

N94-28426# Defence and Civil Inst. of Environmental Medicine, North York (Ontario). Environmental Physiology Section.

FUELLING SHIVERING IN HUMANS DURING COLD WATER IMMERSION

I. JACOBS *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 3 p (SEE N94-28420 08-51) Oct. 1993

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Military cold survival research has traditionally concentrated on ways of conserving body heat. In contrast, this paper will describe recent investigations of metabolic heat production during cold exposure. In humans, increased heat production in the cold is achieved by increased shivering, i.e. involuntary intermittent skeletal muscle contractions, which must be fuelled. This research has focused on the thermoregulatory effects of manipulating the availability of specific fuel substrates to the shivering musculature. Using procedures such as muscle biopsies to quantify intramuscular substrate utilization, venous blood sampling to quantify circulating substrates, and continuous monitoring of metabolic rates and rectal temperatures during cold exposure, the importance of skeletal muscle carbohydrates stores has been demonstrated for the ability to maintain heat production and delay the onset of hypothermia during cold water immersions. Acute reductions in muscle carbohydrate stores were associated with significant reductions in heat production by the body during shivering, and a more rapid decrease in rectal temperature. In contrast, another series of studies induced acute reductions in circulating fat stores, but there was no effect on body temperature regulation. The availability of sufficient carbohydrate stores to the shivering musculature seems to be critical for the body's ability to delay hypothermia during acute cold stress. Author (revised)

N94-28427# Defence and Civil Inst. of Environmental Medicine, North York (Ontario). Environmental Physiology Section.

BIOCHEMICAL ENHANCEMENT OF COLD TOLERANCE

A. L. VALLERAND *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993

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It is well established that humans have a poor resistance to cold. Once the insulation provided by the microclimate and by peripheral vasoconstriction has been maximized, the last line of defense against the cold resides in an increase in metabolic heat production (M-dot). Several techniques have been used to further enhance M-dot in the cold, but it is a pharmacological approach that has received the most support. To that effect, recent experiments in cold-exposed subjects have shown that the ingestion of ephedrine (E; a decongestant) and caffeine (C; a methylxanthine) improves M-dot, heat debt (body heat deficit), and the drop in body core (rectal) temperature T(sub re), (P less than 0.05). The ingestion of an E, C, and theophylline (T; a bronchodilator) capsule produced about the same beneficial effect (P less than 0.05). Although some authors have reported that T alone reduces the drop in T(sub re) (i.e. warmer T(sub re)), these improvements require further clarification since M-dot and mean skin temperature T(sub sk)-bar practically did not change. A theobromine-based (another xanthine) Recreation and Sports bar (Cold Buster) is purported to reduce the drop in T(sub re) and thus delay the onset of hypothermia. However, such claims could not be confirmed in two different studies performed in our lab. Despite an increase in M-dot in some studies, C alone did not alter T(sub re) in the cold. It is concluded that ephedrine/xanthine mixtures represent at the moment, one of the best and safe pharmacological agents to enhance heat production and cold resistance. Author

N94-28428# Manitoba Univ., Winnipeg, Manitoba (Canada). Lab. for Exercise and Environmental Medicine.

TREATMENT OF MILD IMMERSION HYPOTHERMIA BY BODY-TO-BODY AND FORCED-AIR WARMING

GORDON G. GIESBRECHT, IGOR B. MEKJAVIC (Simon Fraser Univ., Burnaby, British Columbia.), DANIEL I. SESSLER (California Univ., San Francisco.), MARC SCHROEDER (California Univ., San Francisco.), and GERALD K. BRISTOW *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 2 p (SEE N94-28420 08-51) Oct. 1993

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The purpose of these studies was to test two methods (one traditional, one recent) for treating mild immersion hypothermia. Derived from text

N94-28429# Army Research Inst. of Environmental Medicine, Natick, MA. Military Health Div.

NUTRITION AND HYDRATION STATUS OF AIRCREW MEMBERS CONSUMING AN IMPROVED SURVIVAL RATION DURING A SIMULATED SURVIVAL SCENARIO

TANYA E. JONES, SUSAN H. MUTTER, JUDY M. AYLWARD, and ELDON W. ASKEW *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 14 p (SEE N94-28420 08-51) Oct. 1993 Prepared in cooperation with Army Natick Research and Development Command

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Adequate nutrition and hydration can be crucial to the survival of downed aircrews. To determine the nutritional adequacy and palatability of an improved, all-purpose, all-environment survival packet (GP-I) compared to the old survival packet (GP), a field test was conducted using combat survival school students. During a five day survival exercise, 41 aircrew members ate the GP-I and 57 ate the GP. Nutrition/hydration status were assessed from food/fluid intake records as well as changes in body weight. Water turnover was measured in a subset of subjects (n=30) using deuterium oxide. Pre- and post-test hemoglobin, hematocrit, plasma osmolality, urine specific gravity (SG) and ketones were also measured. Acceptability of the two rations was evaluated. Subjects eating the GP-I consumed more calories; GP-I 774 +/- 436 versus GP 642 +/- 408 kcal/d. Carbohydrate and protein consumption were similar but the GP-I group ate significantly more fat, 35 +/- 21 versus 24 +/- 18 g/d. Mean fluid intake was similar for both groups (GP-I 4.3 +/- 1.7, GP 4.4 +/- 1.9 L/d). Sodium intakes were 1.1 g/d. Weight decreased significantly for the GP-I and GP groups (2.9 +/- 1.4, 3.4 +/- 1.7 kg, respectively); changes were similar between groups. Water turnover data indicated subjects maintained adequate hydration as did hemoglobin, hematocrit, and plasma osmolality. Mean post-test urine SG was 1.024 +/- 0.007 and moderate amounts of ketones were detected in urine. Both rations received favorable ratings, but the greater variety of the GP-I ration resulted in higher acceptability ratings. Either ration is adequate; however, the GP-I is more desirable and palatable than the GP. Author

N94-28434# Institute for Perception RVO-TNO, Soesterberg (Netherlands).

DETERIORATION OF MANUAL PERFORMANCE IN COLD AND WINDY CLIMATES

H. A. M. DAANEN *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 10 p (SEE N94-28420 08-51) Oct. 1993

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Manual performance during work in cold and windy climates is severely hampered by decreased dexterity. In this study, the quantitative performance decrease is investigated as a function of climatic factors. The decrease in finger and hand dexterity and grip force was quantified for nine combinations of ambient temperature (-20, -10, and 0 C) and wind speeds (0.2, 4, and 8 ms(exp -1)), controlled in a climatic chamber. Finger dexterity was determined by the Purdue pegboard test, hand dexterity by the Minnesota manual dexterity test, and grip force by a hand dynamometer. Twelve subjects with average to low fat percentage were exposed to cold air for one hour with and without extra insulation by a parka. The subjects were clothed in standard work clothing of the Royal Netherlands Air Force for cold conditions. Extra insulation did affect cold sensation but not manual performance. The deterioration (in percent) in performance is strongly dependent upon Wind Chill Equivalent Temperature (C),

and exposure time (min). In a computer program, the performance decreases and freezing risk is indicated for variable climatic conditions. Derived from text

N94-28438# Royal Danish Navy, Gentofte (Denmark). Health Services.

THERMOREGULATION IN THE EXTREME COLD ENVIRONMENT

LEIF VANGGAARD *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 5 p (SEE N94-28420 08-51) Oct. 1993

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Thermoregulation is normally viewed as the physiological responses aimed towards keeping the deep body temperature constant and high. For this work, this viewpoint is changed, and the human thermoregulation is viewed as those physiological mechanisms that keep the body at an optimal functional state. Here, the extremities and their thermal state is of the highest importance. In the extremities, the arteriovenous anastomoses (AVA's) determine the local temperatures, and by their action also define the thermoregulatory state of the body. The AVA's are centrally regulated, they determine the heat exchange with the environment, and they are the main determinants of the average skin temperature. By following their reactions, man's thermoregulatory state can be ascertained. In the treatment of hyperthermia and hypothermia, these functions are highly relevant. The role of the AVA's place them as a specific thermoregulatory organ responsible for the maintenance of optimal extremity temperatures. Derived from text

N94-28440# Institute of Aviation Medicine, Fuerstenfeldbruck (Germany).

AEROPATHOLOGICAL DIAGNOSIS OF LETHAL HYPOTHERMIA

M. KRAEMER *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 6 p (SEE N94-28420 08-51) Oct. 1993

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The decrease of central body temperature by warmth withdrawal leads in most cases to pathological changes of signal devices as the energy metabolism. The central body temperature may be lowered to 28 to 26 C without irreversible disturbances of life functions occurring. Not earlier as below 26 C rectal temperature life sustaining becomes critical. With continued exposure to cold and missing therapy, hypothermia passes several phases. Below 26 C rectal temperature in a phase of paralysis death occurs with cardiac disturbances like cardiac oscillation and disorders of atrio-ventricular conduction. Findings on the corpses of persons dying by cold exposure are discussed. Findings of a crew member dying after ejection and immersion in cold water are demonstrated and weighted by means of differential diagnosis. Author (revised)

N94-28441# Naval Health Research Center, San Diego, CA.

REWARMING METHODOLOGIES IN THE FIELD

R. S. POZOS, R. L. HESSLINK, J. READING, P. KINCAID, and S. FEITH *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993

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Hypothermia may occur with prolonged exposure to cold air or water. Recovery from hypothermia involves removing the individual from the cold environment and utilizing a rewarming strategy. Three major rewarming strategies include the following: passive rewarming, active external heating, and active internal heating. Controversy continues regarding the best rewarming procedure for use in the field. Author (revised)

N94-28442# Royal Naval Hospital, Haslar (England). Dept. of Accident and Emergency Medicine.

A COMPARISON OF FOUR METHODS OF REWARMING INDIVIDUALS COOLED BY IMMERSION IN COLD WATER

C. J. CAHILL, P. J. BALMI (Surrey Univ., Guildford, England.), and M. J. TIPTON (Institute of Naval Medicine, Alverstoke, England.) *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993

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It has been suggested that hypothermia individuals could be actively rewarmed in the field by immersion of only the extremities (hands and feet) in hot water. If successful this technique would have enormous potential in the pre-hospital and hospital care of the victims of accidental hypothermia. The theory is that local heat to the extremities results in opening of the arteriovenous anastomoses with return of warmed blood directly to the core, via the superficial veins bypassing the intervening cold peripheral tissues. A comparison of four techniques for rewarming subjects with lowered core temperatures has been undertaken. The techniques examined were: immersion to the neck in water at 40 C; immersion of one hand in water at 40 C; immersion of two hands plus forearms in water at 42 C; and passive rewarming. During rewarming, core and skin temperatures, heart rate, blood pressure, oxygen consumption, and peripheral blood flow were measured at frequent intervals. No significant difference, in the ability to raise the core temperature, was found among the techniques. It is concluded that hand rewarming, although theoretically attractive, does not work in practice and may even be detrimental in some circumstances, by suppressing intrinsic heat production. Author (revised)

N94-28448# Naval Aerospace Medical Research Lab., Pensacola, FL. Environmental Physiology Div.

EFFECTS OF THREE HYDRATION BEVERAGES ON EXERCISE PERFORMANCE DURING 60 HOURS OF SIMULATED DESERT EXPOSURE

L. G. MEYER, D. J. HORRIGAN, JR., H. M. NEISLER, and W. G. LOTZ *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 10 p (SEE N94-28420 08-51) Oct. 1993

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Without adequate hydration, profound heat stress and dehydration can occur in military forces operating in hot environments. The purpose was to evaluate the effectiveness of three beverages on temperature regulation, cardiovascular response, and work performance during prolonged heat exposure. Nine male subjects, attired in standard military combat uniforms, lived in a climatic chamber for 3 days (60 h) in simulated desert conditions varying from 25 to 45 C, 20 percent relative humidity. Three submaximal treadmill exercise bouts (40 min at 4.8 km/h, 0 percent grade) were performed at 4-h intervals each day. Subjects randomly consumed three beverages: a water placebo of water, citric acid, and aspartame (WP); a 5 percent carbohydrate drink containing water, citric acid, sucrose, fructose, and electrolytes (CE); and a 4 percent carbohydrate drink containing water, citric acid, sucrose, glucose, electrolytes, pyruvate, and 1 percent glycerol (CEG). Subjects drank only one of the three beverages ad libitum during the 60 h but were encouraged to drink every 15 min during exercise. Each subject tested all three beverages in a double blind, repeated-measures experimental design. Sweat rate (SR), core (rectal) temperature (Tre), average skin temperature (Tsk), heart rate (HR), oxygen consumption (VO2), and subjective ratings of perceived exertion (RPE) were recorded during exercise. Body temperatures and metabolic parameters remained within expected physiologic limits during 60 h of simulated desert conditions. During exercise, RPE and HR were similar for all beverages, but VO2, Tre, Tsk, and SR differed among beverages. During the 3rd exercise session on all days, VO2 was higher for CE than CEG and WP; CEG tests had the lowest VO2 on the 2nd and 3rd days. Rectal temperature was lower with CE and CEG than with WP on the 2nd and 3rd exercise periods of each day. Skin temperatures were different during the second exercise period on all three days. Exercise sessions with CEG produced the highest SR. It was concluded that carbohydrate-electrolyte beverages, preferably with a small amount of glycerol, may provide beneficial physiological responses during exercise in hot-dry

conditions during the first 24 h of exposure. However, water alone appears to provide adequate hydration for working in desert conditions over extended periods of time. Author (revised)

N94-28449# Defence and Civil Inst. of Environmental Medicine, North York (Ontario).

ALLEVIATION OF THERMAL STRAIN IN THE CF: KEEPING OUR COOL DURING THE GULF CONFLICT

J. FRIM, L. L. BOSSI, K. C. GLASS, and M. J. BALLANTYNE *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 10 p (SEE N94-28420 08-51) Oct. 1993

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Thermal stress can be a serious problem for military personnel. This is largely because the measures employed to reduce such stress under normal working conditions are impractical under operational circumstances. For example, the specialized clothing worn by soldiers cannot generally be removed to reduce insulation and facilitate cooling. Similarly, operations are often conducted in hostile environments where ambient conditions, even inside vehicles, cannot be altered substantially. While reductions in work rate are feasible during peacetime, they have little place in combat as they compromise objectives and may still not be adequate to reduce thermal strain to acceptable levels. When operationally feasible, the provision of personal cooling can assist the body with heat dissipation and thermoregulation, often to the point that work can be continued at a near-normal rate with only slight to moderate thermal strain. An overview of personal cooling technology studies conducted at DCIEM within the last decade is presented. It outlines the problems of thermal stress in operations and its effects on performance, examines various solutions to the problem, and summarizes the R&D efforts that culminated in the integration of personal cooling into the CH124 Sea King helicopters during Op Friction. This was to our knowledge the world's first use of air crew personal cooling garments during combat and it enabled the Canadian Forces (CF) to conduct their Sea King helicopter operations without being time-limited due to thermal physiological strain. Author

N94-28450# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France). Centre d'Essais en Vol.

EXPERIMENTAL EVALUATION OF TWO SYSTEMS OF INDIVIDUAL AIR-CONDITIONING [EVALUATION EXPERIMENTALE DE DEUX SYSTEMES DE CLIMATISATION INDIVIDUELLE]

D. LEJEUNE, J. M. CLERE, M. BEAUMONT, and M. LONCLE *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993 In FRENCH

(AGARD-CP-540) Copyright Avail: CASI HC A02/MF A03

The thermal stress in military aeronautics can involve a drop in physical and psychomotor performances; in particular the tolerance for accelerations is decreased. The use of a system of individual air-conditioning is likely to decrease the storage of heat and to thus allow the prolongation of missions. Two techniques are possible: a circulation of cooled fluid in contact with the body or a ventilation of cooled air inside the suit. Two systems were tested, one using a cooled water circulation, the other a circulation of air saturated with 20 C water vapor. The fluid, air, or water circulating in contact with the body is cooled using thermoelectric modules. The tests carried out on voluntary human subjects, in a hot environment going from 40 to 50 C, made it possible to highlight a clear improvement in thermal comfort. Each system has advantages and disadvantages. They must undergo technological improvements in order to allow their use on board combat aircraft. Author

N94-36338# Aerospace Medical Research Labs., Brooks AFB, TX. Sustained Operations Branch.

DETERMINANTS OF SUBJECTIVE FATIGUE FOR C-141 CREWS DURING OPERATION DESERT STORM

JONATHAN FRENCH, KELLY J. NEVILLE, WILLIAM F. STORM, ROGER U. BISSON, and PATRICIA BOLL *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 12 p (SEE N94-36321 11-05) Nov. 1993

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As aircraft flight endurance capabilities increase, the importance of attenuating fatigue during long duration missions increases. Profile of Mood States (POMS) data were used to document cumulative fatigue and to explore the relationships between mission characteristics and changes in mood of C-141 aircrew members during Operation Desert Storm. In particular, this research assessed the effects of increasing the limit of 30-day cumulative flight for long duration transport crews from 125 to 150 hours. POMS data were collected at the beginning of the legal for alert (LFA) and crew rest (CR) intervals. Correlational analyses were used to compare POMS dimensions (anger, depression, confusion, fatigue, vigor, tension) with 13 flight and sleep schedule variables. During both LFA and CR intervals, 30-day cumulative flight hours were not related to subjective mood dimensions. However, when 30 day cumulative flight hours exceeded 125 hours, POMS vigor was decreased by recent flight and sleep hours. Therefore, attending to recent sleep and flight history may predict decrements in vigor when operational pressures require exceeding the normal cumulative flight hours per month. A first attempt to construct a crew rest equation is proposed that accounts for these factors. This equation is based on a stepwise multiple regression procedure which revealed that vigor and fatigue were best predicted by cumulative 24-hour sleep and 48-hour flight time. In addition to improved crew rest schedules, dedicated crew rest facilities and sleep hygiene instruction are recommended before flying long duration missions. Author

N94-36339# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Bretigny sur Orge (France).

SOME SOLUTIONS TO REDUCE THE HUMAN EFFECTS OF EXTENDED OPERATION TIMES [QUELQUES SOLUTIONS POUR REDUIRE LES EFFETS SUR L'HOMME DES OPERATIONS DE LONGUE DUREE]

D. LAGARDE and D. BATEJAT *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 17 p (SEE N94-36321 11-05) Nov. 1993 In FRENCH

(AGARD-CP-547) Copyright Avail: CASI HC A03/MF A03

Mostly, in aeronautical environment, the extended operation times assume the continued operations aspect with long duration flights, sometimes transmeridian. In this operations setting, the fast and repeated passing of several time zones is attended with the classical symptomatology of 'jet-lag', intensified by the conditions of the mission. The appearance and the extent of 'jet-lag' are variable according to the flight and the involved subject characteristics; nevertheless, the psychomotor performances decrease is a constant factor of these disorders. In order to investigate with a greater accuracy this aspect in laboratory, the authors present a study model represented by the STRES battery, an ensemble of seven psychomotor tests, recommended by the working group n degrees 12 of the AGARD/NATO, that allows the evaluation of the whole psychomotor register of a subject situated in stress environmental conditions, in a broad meaning. Two examples of these tests to sleep deprivation states are introduced so as to illustrate the sensibility and the interest of implementing this test battery. In view of the disorder's penalizing effect, several authors have postulated solutions in order to suppress or at least to reduce the duration and importance of such symptoms. Thus, some accurate instructions have been recommended relating to the maximum workload condition that can not be exceeded and to the dual aircrew. Others have enjoined to be synchronized with the new time table before departure or to strengthen the social 'zeitgeber' at arrival. Phototherapy, naps, dietetic measures, and physical exercise are also a part of the suggested steps. The pharmacological approach with the use of caffeine, hypnotics, and more recently melatonin have a new lease of interest especially with the appearance of new awakening drugs, as powerful as amphetamines but without their secondary effects. Thus, after the justification of the stimulating drugs' use in the setting of wake sleep rhythms desynchronization, the authors present concisely the modafinil, main representative of this new molecule category. Then, from examples from the laboratory, on occasion of psychomotor performance evaluation with the STRES battery on subjects under sleep deprivation, or on field, they present some results obtained after dispensation of this drug. At the end of this review and of the experimental results, it appears that the extended operation times induce wake-sleep rhythm and psychomotor performances disorders. Numerous possibilities, complementary, exist in order to reduce the observed disorders; none of them appears alone sufficient. Nevertheless, the new

awakening drugs appearance, on account of their great efficiency and their whole inocuity, should constitute a major element in biological rhythms resynchronization in the future.

Author (revised)

N94-37263*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

PROFILE ANALYSIS OF AFTER-EFFECTS EXPERIENCED DURING EXPOSURE TO SEVERAL VIRTUAL REALITY ENVIRONMENTS

ROBERT S. KENNEDY (Essex Corp., Orlando, FL.), MARSHALL B. JONES (Hershey, Milton S. Medical Center, Hershey, PA.), MICHAEL G. LILIENTHAL (Defense Logistics Agency, Alexandria, VA.), and DEBORAH L. HARM *In* AGARD, Virtual Interfaces: Research and Applications 9 p (SEE N94-37261 12-53) May 1994

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Motion sickness symptoms are an unwanted by-product of exposure to virtual environments. This problem is not new and was reported in the early flight simulators and experiments on ego motions and vection. The cardinal symptom of motion sickness is, of course, vomiting, but this symptom is ordinarily preceded by a variety of other symptoms. In his classic studies of motion sickness conducted before and during World War II, G. R. Wendt introduced a three point scale to score motion sickness beyond a vomit/no vomit dichotomy. Later, Navy scientists developed a Motion Sickness Questionnaire (MSQ), originally for use in a slowly rotating room. In the last 20 years the MSQ has been used in a series of studies of air, sea, and space sickness. Only recently, however, has it been appreciated that symptom patterns in the MSQ are not uniform but vary with the way sickness is induced. In seasickness, for example, nausea is the most prominent symptom. In Navy simulators, however, the most common symptom is eye strain, especially when cathode ray tubes are employed in the simulation. The latter result was obtained in a survey of over 1,500 pilot exposures. Using this database, Essex scientists conducted a factor analysis of the MSQ. We found that signs and symptoms of motion sickness fell mainly into three clusters: 1) oculomotor disturbance, 2) nausea and related neurovegetative problems, and 3) disorientation, ataxia, and vertigo. We have since rescored the MSQ results obtained in Navy simulators in terms of these three components. We have also compared these and other profiles obtained from three different vitual reality systems to profiles obtained in sea sickness, space sickness, and alcohol intoxication. We will show examples of these various profiles and point out simularities and differences among them which indicate aspects of what might be called 'virtual-reality sickness'. Author

N94-37276# Naval Aerospace Medical Research Lab., Pensacola, FL. Acceleration Div.

ATTENUATING THE DISORIENTING EFFECTS OF HEAD MOVEMENT DURING WHOLE-BODY ROTATION USING A VISUAL REFERENCE: FURTHER TESTS OF A PREDICTIVE HYPOTHESIS

B. D. LAWSON, F. E. GUEDRY, A. R. RUPERT, and A. M. ANDERSON *In* AGARD, Virtual Interfaces: Research and Applications 14 p (SEE N94-37261 12-53) May 1994

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Research has shown that when subjects are seated upright and asked to perform an earthward head movement in the dark during whole-body rotation, they find the head movement disorienting if it is preceded by prolonged rotation of constant velocity, but not if it is made during the initial acceleratory phase of rotation. The disorienting effects of a head movement after prolonged constant velocity rotation can be attenuated by providing a visual reference to the Earth before the head movement. However, humans may not respond to vestibular or optokinetic simulation the same way for different planes of motion. We tested the disorienting effects of an earthward head movement during rotation about a vertical axis to see if the attenuating effect of a visual reference would be altered. Some subjects were tested while lying on their side and some while lying on their back. Subjective reports concerning head movements in the dark were similar to previous research, suggesting that an acceleratory stimulus in the plane of rotation will attenuate disorientation, regardless of the plane of rotation tested. Likewise, the visual reference attenuated the disorientation that is usually associated with a head movement following prolonged constant velocity rotation. However, the visual reference did not appear to exert as strong an attenuating effect as it had for subjects seated upright. The implication of this finding for the design of centrifuge-based flight simulators is discussed. Author

N94-37277# Army Personnel Research Establishment, Farnborough (England). Special Psychology Research Group.

SOME SIDE-EFFECTS OF IMMERSION VIRTUAL REALITY

E. C. REGAN *In* AGARD, Virtual Interfaces: Research and Applications 8 p (SEE N94-37261 12-53) May 1994

(AGARD-CP-541) Copyright Avail: CASI HC A02/MF A02

Virtual reality (VR) has become increasingly well-known over the last few years. However, little is known about the side-effects of prolonged immersion in VR. The main study described in this paper set out to investigate the frequency of occurrence and severity of side-effects of using an immersion VR system. Out of 150 subjects 61 percent reported symptoms of malaise at some point during a 20 minute immersion and 10 minute post-immersion period. These ranged from symptoms such as dizziness, stomach awareness, headaches, eyestrain, and lightheadedness to severe nausea. Some research which has been conducted which attempted to identify those factors that play a causative role in the side-effects of the VR system is discussed. Finally, some areas for future research are highlighted. Author

N95-19413# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

THE CLINICAL BASIS FOR AEROMEDICAL DECISION MAKING [LES BASES CLINIQUES POUR LA PRISE DE DECISION DANS LE DOMAINE AEROMEDICAL]

Sep. 1994 257 p In ENGLISH and FRENCH Symposium held in Palma de Mallorca, Spain, Apr. 1994

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This symposium addressed the rationale behind aeromedical decisions. Lack of available data required decision-makers to be conservative when deciding who should fly or not. Papers in this symposium updated available data and provided a focal point for discussion and re-evaluation of aeromedical selection and retention standards. Discussion periods allowed for open exchange on particular topics of concern, i.e., cardiovascular and neurological problems and HIV. Our purpose was to exchange data, experience, and management rationales dealing with the very difficult task of aeromedical decision-making. Information sharing would enable nations to update management protocols based upon experience and collectively more powerful data. The elimination of costly redundant research, the focusing of future research, and collaborative efforts between AGARD member nations is the hope of this exchange. For individual titles, see N95-19414 through N95-19443.

N95-19414# Air Force Systems Command, Bolling AFB, Washington, DC. Medical Operations Agency.

AEROMEDICAL RISK MANAGEMENT FOR AIRCREW

T. M. GIBSON (Royal Air Force, Farnborough, England.) and P. M. GIOVANETTI *In* AGARD, The Clinical Basis for Aeromedical Decision Making 8 p (SEE N95-19413 05-52) Sep. 1994

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Medical waivers for aircrew are exceptions to aeromedical standards which have operational justification. The goal of the waiver process is to preserve flying experience to the fullest extent while preserving flight safety, individual health and mission completion. Unfortunately, the flight surgeon has historically been forced to be conservative in deciding who was or who was not fit to fly because of a paucity of relevant scientific data. Moreover, the waiver process has not always been applied logically or consistently. The US Air Force has recently applied the philosophy of aeromedical risk management to produce a waiver guide for flight surgeons. The guide lists the aeromedical concerns for selected chronic conditions met by the flight surgeon. Advice is given on the workup required for each waiver request and a discussion section examine the rationale for the aeromedical disposition. For each condition, an indication is given of the US Air Force waiver experience over the last few years. This paper examines the basic philosophy and describes the use of the waiver guide. Author

N95-19415# Belgian Air Force, Brussels (Belgium).
THE WAY TO WAIVERS IN THE BAF
J. P. VASTESAEGER and P. VANDENBOSCH *In* AGARD, The Clinical Basis for Aeromedical Decision Making 4 p (SEE N95-19413 05-52) Sep. 1994
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The medical and physical examinations our pilots go in for at recruiting and during their annual revision become more extended and accurate thanks to new medical techniques. On the other hand we notice that the importance of human factors as a cause of flight accidents increases. Therefore, the medical Commission (GCGLUD) responsible for declaring pilots fit to fly has to describe the affections regarding to risks and prognosis in more detail, and has to impose flight restrictions adapted to the type of airplane and the function of the pilot involved. The medical Commission for suitability to fly's decision thus has an important influence on the further career of the pilot in question and on flight safety in common. The Commission has to find a balance between common and personal interest. The main intention of this study was to critically evaluate the procedures followed by the Commission, based on an investigation on the cases of all pilots, in the Belgian Airforce, who were restricted definitely during the year of 1992. The population, the different kinds of affections and the resulting flight restrictions were studied. These data will be followed by a critical view on the method of procedure of the Commission.
Author

N95-19416# Naval Aerospace Medical Inst., Pensacola, FL.
THE WAIVER PROCESS AND DISQUALIFYING MEDICAL CONDITIONS IN US NAVAL AVIATION PERSONNEL
DEAN A. BAILEY, LOUIS G. GILLERAN, and P. GLENN MERCHANT *In* AGARD, The Clinical Basis for Aeromedical Decision Making 11 p (SEE N95-19413 05-52) Sep. 1994
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In the United States Navy, many diagnoses are considered disqualifying for aviation duty but may be 'waived' to return to flight duties after resolution of the disease or appropriate treatment of the condition. Personnel with waivers are usually subject to more frequent physical examinations and/or special diagnostic procedures. Although the Naval Aerospace and Operational Medical Institute promulgates written aeromedical guidelines that delineate which disease conditions may be waived and which may not, waivers are granted on a case-by-case basis considering not only the diagnosis, but the age, experience, and type of aviation duty of the individual in question. This study was undertaken to determine which conditions were most and least likely to be waived. We reviewed all cases entered in the Naval Aviation Medical Data Bank who had been diagnosed with a condition considered disqualifying for aviation duty, totaling over 39,000 records. Cases were stratified by diagnosis and aviation duty and the percentage waived was calculated for major diagnostic groups. Approximately 66% of all cases with a disqualifying diagnosis were recommended for a waiver. Otolaryngologic, ophthalmologic and musculoskeletal disorders accounted for over 50% of diagnoses in personnel recommended for a waiver. Fear of flying, personality disorders and adjustment disorders were the three diagnoses least likely to be granted a waiver. The most common disqualifying diagnoses of aviation personnel not recommended for waiver were disorders of refraction and accommodation, obesity, allergic rhinitis, alcohol dependence, and hypertension. Designated aviation personnel were significantly more likely to be waived than students. Author

N95-19417# Naval Aerospace Medical Inst., Pensacola, FL.
THE EFFECT OF SPECIAL BOARDS OF FLIGHT SURGEONS ON THE EVOLUTION OF US NAVAL FLIGHT STANDARDS
K. L. GALLAGHER and E. A. BOWER *In* AGARD, The Clinical Basis for Aeromedical Decision Making 5 p (SEE N95-19413 05-52) Sep. 1994
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The flight surgeon is frequently asked to make a determination on the 'fitness to fly' of a member of his or her squadron. Common medical conditions that are transient, unlikely to progress in the operational environment, and have no sequelae that could compromise safety of flight do not result in the physical disqualification of the aviator. These simple cases lend themselves to a prompt aeromedical disposition and are routinely handled by the squadron flight surgeon through the issuance of temporary grounding notices. Following resolution of the acute illness, the aviator can immediately return to full flight status. If any of these prerequisites are not met, however, the aeromedical disposition becomes more complex. Medical conditions that may have significant sequeale, require long term follow up, or those that require chronic medication are not compatible with existing Naval aviation physical standards. If the aviator's career is to be preserved, a waiver of physical standards must be obtained. These challenging cases are generally handled by the squadron flight surgeon, with input from higher medical authorities. These recommendations are forwarded to the Bureau of Personnel for final action. The line community is the final arbiter of standards, and will issue a waiver for flight status based on the needs of the service. Since 1956, the U.S. Navy aeromedical community has officially recognized the need for an approach to evaluate aviators with significant fitness for flight questions. In 1957, the Chief of Naval Air Training established a reviewing body of speciality trained flight surgeons at the Naval Aviation Medical Center in Pensacola, Florida. This group became known as the Special Board of Flight Surgeons. The Senior Board of Flight Surgeons can make recommendations that supersede the recommendations of the Special Board of Flight Surgeons, and in effect can serve as the court of last resort for aviators seeking another hearing of their case prior to final recommendation. A Special Board of Flight Surgeons is requested by an aviator's commanding officer. Medical information is supplied to the clinical departments at the Naval Aerospace and Operational Medical Institute (NAMI) and a recommendation on the merits of hearing the case is then made to the commanding officer of NAMI. All special board cases presented at NAMI from 1 January 1984 until 31 December 1993 were reviewed. There were 119 special board cases involving 116 individuals. These individuals appeared before the board on two separate occasions. Pertinent demographic data were entered into a computerized database program (dBase III, Ashton-Tate Inc.) for trend analysis. The rationale for the aeromedical conclusions reached in each of the 119 cases presented in the past ten years was explored in detail. No statistical analyses were attempted on the data. The effect of sex and race on board outcome were considered, however, there were only two females and few minorities during the time frame considered negating any statistical significance. Author

N95-19418# Centro de Instruccion de Medicina Aeroespatial, Madrid (Spain).
FIT TO FLY: ANALYSIS OF THE AEROMEDICAL DISPOSITION IN AIRCREWMEMBERS OF THE SPANISH ARMED FORCES
FRANCISCO RIOS, JOSE A. AZOFRA, PATRICK P. MILES, JUAN J. CANTON, VICENTE VELAMAZAN, and JOSE B. DELVALLE *In* AGARD, The Clinical Basis for Aeromedical Decision Making 14 p (SEE N95-19413 05-52) Sep. 1994
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Medical fitness is an essential part of air safety. Aircrews undergo their regular medical review to ensure their physical and mental status will enable them to carry out their onboard functions in both normal and exceptional circumstances. Medical screening during the selection process followed by continued medical vigilance over the health of aircrews has been the major contributor to air safety by reducing the risk of potential incapacitation during flying duty. Because preexisting disease has been described as a contributor to aircraft mishaps military aviators undergo detailed initial flying physical examinations designed to find those with physical defects or disabilities that could potentially compromise flying safety. Another major objective of the physical examination is to periodically reevaluate conditions already known to the pilot and flight surgeon which may or may not have required the granting of a waiver previously, as there are many medical problems or conditions which are not static but may become improved or worsened over the time interval since the last periodic check up. The decision whether to let a pilot fly again is always a difficult one, especially since the airman involved is usually very keen to return to duty and will do his utmost to convince those who make these decisions that he is capable of flying. Flight surgeons have the responsibility to confirm this capability prior to putting a pilot back in the cockpit. The purpose of this study was: (1) to review the aeromedical disposition of Spanish military personnel through the first half of 1993 and identify the major reasons for permanent or temporary disqualification; (2) to determine the incidence or various medical causes for permanent or restricted status; and (3)

to determine the incidence and reasons for restrictions or temporary disqualification among aviators who, after appropriate follow-up were returned to flying duties. ESDU

N95-19419# Naval Aerospace Medical Inst., Pensacola, FL.
AMDRS: A RESOURCE FOR INTELLIGENT AEROMEDICAL DECISION-MAKING
C. J. NICKLE *In* AGARD, The Clinical Basis for Aeromedical Decision Making 6 p (SEE N95-19413 05-52) Sep. 1994
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The Aviation Medical Data Retrieval System (AMDRS) is a dynamic, expanding database that currently contains information on 150,000 individuals, and approximately 75,000 separate complete examinations. The Naval Aerospace and Operational Medical Institute (NAMI) developed AMDRS in March 1989. The Aviation Epidemiological Data Register (AEDR), developed by the US Army Aeromedical Research Laboratory, is the temporary repository of information from which the AMDRS develops. After the medical record is completed by reviewers, information is transferred for permanent storage in the Aviation Medical Data Base (AMDB). The purpose of this paper will be to provide detail about the information available in the database, examples of previous studies completed, and propose specific areas for future study. Author

N95-19420# Institute of Aviation Medicine, Fuerstenfeldbruck (Germany).
RELEVANCE OF LABORATORY TESTS IN AEROMEDICAL DECISIONS
K. REICHENBACH-KLINKE *In* AGARD, The Clinical Basis for Aeromedical Decision Making 3 p (SEE N95-19413 05-52) Sep. 1994
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Laboratory tests in body fluids are an essential part of the aeromedical examination. It helps to find objective data in a poor anamnesis. Nearly all pilots tell us they feel healthy and fit for flying duty. The chemical finding sometimes give surprising results. Measurements are of a high technical standard, quality control guarantees reliability. So no-one can ignore an abnormal laboratory measure, the range of test profiles in aeromedical examination in civil and military regulations is different. Our laboratory program for pilots is now reformed and will be part of the regulations for the aeromedical examination. The selection of laboratory screening test follows some criteria: (1) relevance for a safety relevant disorder; (2) test is sufficient specific and sensitive; and (3) test can be automated and economically performed. Specials in military duty asymptomatic chronic diseases, which may be aggravated in extreme climate, must be excluded. Author

N95-19421# Italian Air Force Forensic Medical Inst., Rome (Italy).
TSH DETERMINATION IN SUBJECTS WITH MEDIUM-LOW LEVELS OF SERUM THYROXINE
D. DANESE, F. VIAGGI, and O. SARLO *In* AGARD, The Clinical Basis for Aeromedical Decision Making 13 p (SEE N95-19413 05-52) Sep. 1994
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The prevalence of thyroid diseases is almost 5 to 7%. Hypothyroidism, whether primary (thyroidal) or secondary (hypothyrotropic and, rarely, hypothalamic) occurs at all ages and is more common in women. Its frequency varies depending on the population studied. The prevalence of overt hypothyroidism is 0.5 to 2%. Even though hypothyroidism is an uncommon cause of disease, it nevertheless decreases psychological and physiological efficiency, modifying the aeromedical standards. Hypothyroidism is an involved clinical, metabolic condition supported by inadequate thyroid function. Elevation of thyrotropin blood levels is a sensitive indicator of decreased thyroid gland function (primary hypothyroidism). In this study we evaluated the prevalence of subclinical hypothyroidism, characterized by an elevation of TSH levels with low levels of serum thyoxine and medium-low levels of free tiroxine, in subjects examined at the Forensic Medical Institute of IAF, during ordinary checkups. Author

N95-19422# Service de Medecine Aeronautique, Versailles (France).
EKG IN FLIGHT: USEFULNESS AND LIMITS FOR AIRCREW REHABILITATION
A. SEIGNEURIC, J. P. BURLATON, F. DIDELOT, R. CARLIOZ, and P. E. BERTRAN *In* AGARD, The Clinical Basis for Aeromedical Decision Making 5 p (SEE N95-19413 05-52) Sep. 1994
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During the last 16 years, we have performed 86 in-flight EKG's on french aircrew members in order to have additional arguments for fitness decisions. Fighter pilots were the most important group (39%) followed by helicopter pilots (27%), transport pilots (13%) and student pilots (9%). The most important reasons were EKG disturbances and in particular excitability disorders. Cardiac troubles like coronary or valvular disease were more rare. This examination provided positive indication of flying fitness in 70% of cases, negative indications in 15% and no indication in 15% of cases. It is a useful complement to conventional cardiac investigations before medical decision in certain cases. Author

N95-19423# Centro de Instruccion de Medicina Aeroespatial, Madrid (Spain).
EVALUATION OF THE EKG'S ISOELECTRIC T WAVE IN AIR FORCE PILOTS
M. A. GOMEZ-MARINO, F. RIOS-TEJADA, and V. VELAMAZANPERDOMO *In* AGARD, The Clinical Basis for Aeromedical Decision Making 7 p (SEE N95-19413 05-52) Sep. 1994
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171 out of 5126 performed EKG's from aircrew members (3.33%), showed some ST-T wave abnormalities. We studied 23 out of the 171 with isoelectric (low amplitude or moderate inversion, but less than 1 mm) in all leads but not in V2-V3 where the T wave were normal. Six of those, had T wave inversion in III and avF leads. All 23 are healthy males, between 30-55 years old (43.6 plus or minus .3), without associated EKG disorders, ionic alterations, and no one regularly practiced heavy exercise. Each one had had between 3 and 21 (11.5 plus or minus 6.5) EKG recordings along a following period of 3 to 20 years (13.0 plus or minus 6.3). All of them has been evaluated through treadmill test (Bruce protocol, submaximal greater than 90%), Doppler-Echocardiography and 24 hours Holter monitoring. We found in 22 cases (95.6%), echocardiographic criteria of left ventricular hypertrophy (IV septum more than 13 mm). 15 out of 15 were symmetric and 6 were asymmetric. 19 cases (86.4%) had a mitral filling flow pattern typical of left ventricular compliance disorder, with atrial wave (A) bigger than fast filling wave (E). Only 3 cases (13.6%) had normal mitral flow Doppler pattern. Valvular or subvalvular aortic gradient was not found in any case. Bruce test results were negative in all cases, but in 21 of those (91.3%), during exercise or the first minute of recovery, T waves became normal, returning to be isoelectrics before 10 minutes. We conclude that asymptomatic flyers without coronary risk factors with isoelectric T waves in all EKG leads (but normals T waves in V2-V3), with or without T inversion in III and avF leads, should be adequately tested in order to rule-out mild hypertrophic myocardiopathy, by Doppler-Echocardiography, and not focus attention in trying to find coronary artery diseases. Author

N95-19424# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
CENTRIFUGE TESTS OF THE MEDICAL CONDITION OF FRENCH FIGHTER PILOTS [EPREUVE EN CENTRIFUGEUSE DANS LE CADRE DE L'APTITUDE MEDICALE DES PILOTES DE CHASSE FRANCAIS]
G. OSSARD, A. SEIGNEURIC (Service de Medecine Aeronautique, Versailles, France.), J. M. CLERE, and J. P. BURLATON (Service de Medecine Aeronautique, Versailles, France.) *In* AGARD, The Clinical Basis for Aeromedical Decision Making 8 p (SEE N95-19413 05-52) Sep. 1994 In FRENCH
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The performance of piloting may be involved with processes of which the etiology is not well known today. In the French Air Force, after a serious illness, the pilots undergo a medical examination of their condition to resume flying. Therefore, in order to insure that no risk remains due to accelerations, the pilots undergo a standardized centrifuge test in the Aerospace Medicine Laboratory. From 1983 to 1993, 112 centrifuge tests were

conducted. The requirement for having a centrifuge test is largely predominated by illness of loss of consciousness and cardio-vadcular disturbances which are essentially transitory electrocardiograph anomalies. In certain cases, the disorders have been reproduced and analyzed. The centrifuge test frequently permit avoidance of a disqualification which would have grave consequences for the pilot, based on physiological findings, and for the savings to the Air Force of an investment in operational status. Author

N95-19425# Royal Norwegian Air Force, Oslo (Norway). Inst. of Aviation Medicine.

IS THE PILOT FIT FOR FLYING AFTER AN ACCIDENT?

GRETE MYHRE *In* AGARD, The Clinical Basis for Aeromedical Decision Making 3 p (SEE N95-19413 05-52) Sep. 1994
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It has been recommended that a pilot should fly as soon as possible after an aviation accident or incident, provided he is medically fit. This tradition has been successful in many cases and has therefore been accepted as the right thing to do in the flying society. New knowledge about post traumatic reactions related to accidents has led to new procedures in the Royal Norwegian Air Force in the wake of a crash. Since an accident necessarily affects many persons, much like rings in the water after throwing a pebble, the new post accident debriefing procedures cover the involved parts after a survivable accident in addition to the rest of the squadron. A considerable problem with post traumatic emotional reactions are that they are not usually detected right after the accident, but are elements in a process rather than immediate results of the acute event. So far this program has demonstrated two effects: (1) maintaining the confidence level the aviator had prior to the accident, and (2) demystifying normal emotional reactions in flying personnel, which in itself is a very important accomplishment. In conclusion, the pilot is fit for flying when he has been made aware of the emotions connected with an accident and what to do if and when they appear. The pilot will be able to continue his duties if he has a supportive team that he can lean on in the first period of time after his traumatic experience. For most people it is an advantage to get back to work and resume the normal activities as soon as possible. The aviator will be able to execute his duties without limitations, knowing that the emotions he has gone through are normal and expected, provided the flight surgeon has performed this part of his job carefully. Author

N95-19426# Naval Aerospace Medical Inst., Pensacola, FL.

THE CONCEPT OF AERONAUTICAL ADAPTABILITY AS DEVELOPED BY THE US NAVY

P. G. MERCHANT and J. C. BAGGETT *In* AGARD, The Clinical Basis for Aeromedical Decision Making 7 p (SEE N95-19413 05-52) Sep. 1994
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Physicians working in the field of aviation medicine have known from the earliest days of the specialty that the psychological fitness of aviators was a critical element in minimizing aircraft accidents. Studies, spanning 8 decades of aviation, have demonstrated that the majority of aviation accidents have been the result of human factors. Selection of psychologically fit candidates and monitoring the status of designated Naval Aviation personnel has thus been one of the major tasks performed by Naval Flight Surgeons. To guide them, the concept of Aeronautical Adaptability has been developed. Composed of two similar but separate concepts, the first one requires the flight surgeon to evaluate the motivation, temperment, flexibility, and appropriate psychological defense mechanisms of aviation candidates. The second concept accepts that once designated, an aviator has proven his ability to adapt to the rigors of aviation. Still, it requires monitoring of the experienced aviator's pattern of coping with the stresses of aviation, and provides the means to find designated personnel not Aeronautically Adaptable should maladaptive behavior affect the safety of flight. This paper will explore the early psychological standards in the U.S. Navy, then discuss Aeronautical Adaptability as it evolved over the last 15 years. It will discuss the rational behind the current concept and show how Aeronautical Adaptability provides a fair, timely system of review to help the U.S. Naval Flight Surgeon process difficult cases that could present an unacceptable safety risk in Naval Aviation. Author

N95-19427# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Soesterberg (Netherlands). Human Factors Research Inst.

VESTIBULAR EXAMINATION IN PILOTS SUSCEPTIBLE TO MOTION SICKNESS

WILLEM BLES, BERND DEGRAAF, and JELTE E. BOS *In* AGARD, The Clinical Basis for Aeromedical Decision Making 8 p (SEE N95-19413 05-52) Sep. 1994
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An analysis is presented of data obtained from vestibular examinations on student pilots prone to airsickness. It is shown that those pilots who were most susceptible during the initial flight training course, in the laboratory even suffered from mild conditions of the Coriolis test. Abnormal postural behavior in the tilting room test, or long time constants of the nystagmus decay after sudden stops from constant velocity rotation, do not contra-indicate a successful desensitization program. A Practical Flying Selection considerably diminishes the number of student pilots suffering from airsickness. Those who pass this test, but got nevertheless into motion sickness trouble during the pilot training, were successfully treated with a desensitization program. Author

N95-19428# Naval Aerospace Medical Inst., Pensacola, FL.

THE NAMI SYNCOPE TEST BATTERY AND CLINICAL DECISION-MAKING IN AVIATORS WITH SYNCOPE

J. R. DEVOLL and E. W. HOPKINS *In* AGARD, The Clinical Basis for Aeromedical Decision Making 9 p (SEE N95-19413 05-52) Sep. 1994
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The Syncope Test Battery (STB) was adopted in 1988 at the Naval Aerospace and Operational Medicine Institute (NAMI) to provide a coherent and consistent methodology for the evaluation of physiologic or secondary syncope. Records from 1988-1992 that utilized the STB were reviewed, and STB results were compared against final diagnostic categories of physiologic or secondary syncope ($n=55$). Analysis of the STB showed a sensitivity of 20.6 percent, specificity 100 percent, predictive value positive 100 percent, predictive value negative 43.8 percent, and concordance 50.9 percent. These results failed to support the effectiveness of the STB, and the STB did not result in any change between the preliminary and final diagnoses as made on other clinical bases. The evaluation and disposition of syncopal aviators is reviewed in the light of general and aerospace medical literature. It is concluded that the STB is not a useful tool in evaluating syncope in the US Navy aviation population. A step-wise algorithmic approach is recommended for the evaluation of syncopal aviators, but the eventual disposition must still be individualized and remains problematic for the flight surgeon. Author

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THINK HEALTH NOT DISEASE

HARALD T. ANDERSEN *In* AGARD, The Clinical Basis for Aeromedical Decision Making 5 p (SEE N95-19413 05-52) Sep. 1994
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At air crew selection time many important medical decisions are made, most of them relying on simple clinical methods such as preliminary case history and physical examination. Information obtained using sophisticated laboratory methods may give crucial information when results are evaluated against occupational hazards, but it is important to keep in mind that such procedures are not clinically indicated. Health management of those successfully trained is not performed towards a background of disease but to the contrary, in order to promote health. Retention of those treated for illness is a decision of fitness to fly after evaluation of treatment. Clinicians may be satisfied with the treatment of a patient, flight surgeons may or may not be happy with the result considering the occupational hazards of military aviation. It follows that selection, health management and retention of aviators are in principle considerations of health not of disease. Examinations performed on asymptomatic military aviators using diagnostic high technology instrumentation may not contribute essentially to medical decision making. Author

N95-19430# Divisione Aerea Studi Ricerche e Sperimentazioni, Pratica di Mare (Italy).
NEUROPSYCHOPHYSIOLOGIC SEQUELAE OF MILD HEAD INJURY
ANTONIO BELLI, SILVIO PORCU, and ANDREA BELLATRECCIA *In* AGARD, The Clinical Basis for Aeromedical Decision Making 11 p (SEE N95-19413 05-52) Sep. 1994
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Psychologic or neuropsychologic consequences of severe closed head injury have received much attention in both clinical and experimental studies. Nevertheless, it has been clearly established that even mild closed head-injured patients may develop psychologic or even psychiatric sequelae of clinical relevance, including poor social adjustments as well as cognitive impairment. Symptoms such as dizziness, fatigue, irritability, headaches, insomnia, anxiety, and amnesia are also frequently reported, these being usually the major features of post-concussion syndrome. Cognitive impairment is responsible of attention and concentration capability disorders, with consequent difficulty in retrieving acquired information and performing usual tasks. Full or satisfactory recovery from such symptoms is normally achieved in few months, with persistence in a minority of cases with distinct risk factors (age, gender, multiple trauma, history of previous head injuries). Such manifestations of head trauma are satisfactorily detected and followed up by means of specific neuropsychologic tests in several studies, while CT-scan fails to provide but scarce prognostic reliability. The role of neurophysiology is controversial, although opinions are that it should be referred to in selected cases and in a multidisciplinary approach. Finally, an interesting and significant correspondence of neuropsychologic tests, behavioral data and MRI or SPECT findings casts a new light on both clinical and research aspects of the question. Making a decision whether returning a head-injured pilot to flight activity or not certainly constitutes an additional problem for the risk of epilepsy and of other neurological or neurosurgical complications is to be considered of primary importance even for mild head trauma (which accounts 75 percent or more of the total, with an annual incidence of about 150 per 100,000 population). Neuropsychologic sequelae themselves do require a restriction from flying duties for months or years. It is advisable to await normalization of neuropsychologic and neurophysiologic parameters, in absence of neuroimaging (i.e. MRI) signs, before returning the patient to flight activity. Neurophysiology (EEG, evoked potentials) provides cost-effective, sensible and reproducible means for diagnosis and follow-up and its value could be boosted by the implantation of an individual neurophysiological database for all the flying personnel. Author

N95-19431# German Air Force, Fuerstenfeldbruk (Germany). Inst. of Aviation Medicine.
NEUROLOGICAL DECISION MAKING IN AVIATION MEDICINE BASED ON ELECTROPHYSIOLOGICAL METHODS
H. GLASER and W. FREUND *In* AGARD, The Clinical Basis for Aeromedical Decision Making 7 p (SEE N95-19413 05-52) Sep. 1994
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The task of neurology in aviation medicine is to determine whether a person is without disturbances of the nervous system's function and without elevated probability to show relevant disturbances in future. Besides medical history and clinical examination, decisions are based on technical methods. Concerning image generating methods, testing of higher brain functions, and sonotopographic methods neurology for the most part utilizes the service of the specialities radiology, psychology, and angiology, while application of electro-physiological methods like electroencephalography, electromyography, neurography or examination of evoked potentials are the neurological specialities own methods. The main task of electroence-phalography in aviation medicine in our opinion is to identify persons with an individually higher electrophysiological lability, which is a lower threshold for abnormal activity of the brain. These persons under conditions of military duty bear a higher risk of developing epileptic phenomena, even if they stay asymptomatic under conditions of everyday life. Author

N95-19432# Portuguese Air Force Aeromedical Center, Lisbon (Portugal).
THE EEG IN THE EVALUATION OF APPLICANTS TO AIRCREW MEMBERS
NUNO PEDRO RIBEIRO *In* AGARD, The Clinical Basis for Aeromedical Decision Making 4 p (SEE N95-19413 05-52) Sep. 1994
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The E.E.G. has been used since its beginning as a tool in selection of aircrew personnel. Knowing that even in epileptic patients the E.E.G. in a great majority of cases doesn't show abnormalities, the problem is raised on the meaning of such method in the selection of aircrew candidates. On the other hand we must agree in the definition of a 'normal' E.E.G., and what are the meanings of certain abnormalities in an individual that says that he/she is healthy and denies in his/her clinical history, epilepsy, febrile convulsions, headaches and head traumas. Acording to Niedermeyer and Lops da Silva, the usefulness of the E.E.G. in aircrew selection is that we'll have a record to compare in case of need of repetition of E.E.G. In the Portuguese Air Force the selection is seriated, the neurological observation being one of the last ones and only one small part of all applicants submitted to it. The evaluation consists on a clinical history, in which the denial of all pathology is the rule (they are all voluntary), neurological examination and an E.E.G., 30 minutes duration, in the 10-20 system (since 1990), with two hyperventilations and one photic stimulation. Author (revised)

N95-19433# Queens Medical Centre, Nottingham (England). Dept. of Neurosurgery.
CLINICAL BASIS FOR AEROMEDICAL DECISION-MAKING: THE EEG EXAMPLE
J. L. FIRTH *In* AGARD, The Clinical Basis for Aeromedical Decision Making 8 p (SEE N95-19413 05-52) Sep. 1994
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The EEG, electroencephalogram, is used as a test in aircrew selection. Given that the natural history of the seizure disorders has been described, the validity of this practice is questioned and potentially more rewarding applications of the EEG suggested. System reliability is a major component of aircraft system performance. In military aviation both are central nervous system dependent. In aircrew assessment and management the EEG, electroencephalogram, has traditionally played a major role. Advances in technology, data retrieval, storage, presentation, processing, interpretation and assessment make this an appropriate time to review the place of the EEG in aeromedical decision-making and research. Author

N95-19434# Centro de Instruccion de Medicina Aeroespatial, Madrid (Spain).
SPINE INJURIES: UP TO DATE EVALUATION IN AIRCRAFT EJECTIONS
FRANCISCO RIOS, JOSE A. AZOFRA, PATRICK P. MILES, CARLOS VELASCO, JUAN SIEIRO, and ALFREDO CUEVAS *In* AGARD, The Clinical Basis for Aeromedical Decision Making 6 p (SEE N95-19413 05-52) Sep. 1994
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Spinal injury during aircraft egress has been a well known phenomenon since the early days of flying, though at that time usually secondary to ground impact. However, the development of High Performance Aircraft (HPA) has forced the consequent development of high performance ejection mechanisms. These modern ejection systems have functioned superbly with the latest generation mechanism allowing 91.1 percent survivability when egress takes place above 500 ft from ground level and 79.2 percent pilot survival rate when egress is undertaken at flying level less than 500 ft. However, while the overall success rate of 88 percent has resulted in many more pilots surviving an egress experience, 21 percent of these flyers have been shown to suffer some degree of significant spinal injury (vertebral compression-fracture) during egress, potentially threatening their ability to return to the cockpit. Modern HPA, with their ability to inflict immediate and sustained high +Gz forces to the cockpit environment challenge the flight surgeon now as never before to carefully and successfully evaluate the pilot who has suffered egress-related spinal injury in order to determine whether it will be safe for the flyer to return to such an environment. This challenge is made even more pressing by the fact that pilots who eject are often well-trained, experienced flyers

whose potential lost services, either due to permanent disqualification from flying duties or due to further, additional spinal injury, represent a significant potential loss of valuable human resources to NATO Air Forces, already facing the loss of key personnel and resources due to today's economic pressures. These factors make it imperative that all of the modern medical means at hand be utilized in the analysis of post-ejection spinal injuries.
Author

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CLINICAL PRACTICE, DIAGNOSIS AND THERAPY OF INTERVERTEBRAL DISK LESION: IMPORTANCE TO FITNESS FOR MILITARY FLYING DUTIES

T. PIPPIG *In* AGARD, The Clinical Basis for Aeromedical Decision Making 6 p (SEE N95-19413 05-52) Sep. 1994
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The intervertebral disk, central element of the motion segment, may be exposed to high strains which occur when piloting a jet aircraft or a helicopter. Isolated traumatic ID lesions due to flying strains do probably not come into existence neither ID degeneration according to our actual findings and knowledge of the matter. When there is an accurate diagnosis as to ID prolapse considering clinical and radiological findings, ability for military flying duties is exempted for the next six months. Adequate therapy, either by conservative or surgical treatment, is to be initiated. In the case of cervical ID prolapse however, we do not recognize ability for military flying duties for pilots of jet aircraft seated on an ejection seat and for helicopter pilots, even after good results of treatment. After lumbar ID prolapse and good results of treatment we consider the ability for military flying duties as being restored. Thereafter and when the first flying strains set in, the responsible flight surgeon should examine the pilot regularly, at least in the beginning.
Author

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SPINAL NERVE SYNDROMES: THE NEED TO CONFIRM THE DIAGNOSIS WITH NEUROPHYSIOLOGICAL EXAMINATIONS

WOLFGANG FREUND and H.-J. GLASER *In* AGARD, The Clinical Basis for Aeromedical Decision Making 8 p (SEE N95-19413 05-52) Sep. 1994
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Because even the normally healthy pilots suffer from the usual aging and degeneration of the spine, sudden g-stress may lead to compressions of spinal nerves if degenerated intervertebral discs protrude into the intraspinal space. To avoid risks to general flight-safety as well as to the pilot's health, back-pain and sciadic syndromes have to be evaluated aeromedically. The common methods to investigate the cause of spinal-nerve affections can be divided into three steps: first the intensified interrogation and clinical examination of the pilot, which usually leads to the rough specification of the location of the lesion as well as a first hypothesis of the cause (e.g.: A probably traumatic lesion of the left first thoracal nerve). Second usually come radiological methods such as X-ray of the spine and, more promising, a X-ray computer-tomography (CT) and in difficult cases magnetic-resonance-imaging (MRI), which can differentiate between tumors and protusions of intervertebral discs. In the third step the extent of the damage is evaluated by neurophysiological methods. From the viewpoint of aeromedical decision-making this step is the most critical. Of the suitable methods there are the following used the GAF Institute of Aviation-Medicine (GAFIAM): Electromyography: Fast, rather accurate and reliable, though it covers only the motorical part of the nerve-root); Neurography (F-wave measurements can detect lesions in the motorical part of the nerve-root); Somatosensory Evoked Potentials (SEP) (though time-consuming and demanding they offer the only way to measure sensory deficits); and Magnetically Evoked Potentials. To illustrate the decision-making process, examples are demonstrated.
Author

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THE AEROMEDICAL IMPLICATIONS OF SUPRAVENTRICULAR TACHYCARDIA

LONDE A. RICHARDSON and PAUL V. CELIO *In* AGARD, The Clinical Basis for Aeromedical Decision Making 5 p (SEE N95-19413 05-52) Sep. 1994
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Supraventricular tachycardia (SVT) is uncommon in healthy screened populations and has an overall prevalence of 0.02 percent and a maximal prevalence Of 0.1 percent on routine screening electrocardiograms (2-8), 4.6 percent on Holter monitors (9-12) and approximately 0.6 percent on treadmills (13, 14). A review of the clinical literature reveals that occupational and aeromedical risks for aviators with SVT remains inadequately addressed. Long term follow-up data in aviators with SVT is limited to a single small series by Matthewson and Varnam who followed four aviators for 14 years and found no deaths or coronary events. The Aeromedical Consultation Service (ACS) is a centralized United States Air Force (USAF) referral center which performs aeromedical evaluations in aviators to determine their fitness for flying. The ACS has evaluated aviators with SVT since 1955. In 1973, the ACS developed a protocol permitting resumption of flying duties in aviators with SVT; waivers were granted in selected low aeromedical risk cases. We have continued to provide clinical follow-up of aviators with SVT to insure that waivers for SVT are recommended only in low aeromedical risk cases. Although uncommon, SVT can present suddenly with presyncope, syncope or sudden death with potentially catastrophic results during flying duties. Aviators with SVT were disqualified historically because of these risks. Medical standards must be conservative to insure that USAF aviators are free of such conditions. However, this conservative approach has disqualified many asymptomatic aviators who may have safety flown if data had been available demonstrating that certain subsets had an acceptably low aeromedical risk. When evaluating an aviator with SVT, waiver authorities must determine the extent of aeromedical risk, the level of risk acceptable for continued flying duties and which waiver restrictions should be applied. This paper provides outcome data, acquired from aviators with various SVT presentation profiles to assist in that risk stratification. With these data, a safe return to flying duties for those aviators with acceptably low levels of aeromedical risk can be achieved.
Author

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SARCOIDOSIS IN US MILITARY AVIATORS

ROBERT MUNSON, B. TUOMALA, PAUL V. CELIO, and LONDE A. RICHARDSON *In* AGARD, The Clinical Basis for Aeromedical Decision Making 3 p (SEE N95-19413 05-52) Sep. 1994
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Sarcoidosis is a systemic granulomatous disease of unknown etiology and is generally a benign, self-limiting disorder. Myocardial involvement has been known since 1929, but several articles published in the early 1970's indicated that myocardial involvement was a more common and serious problem. In 1974, Fleming reported on 50 cases of myocardial sarcoidosis with cardiac involvement confirmed in 20 cases by necropsy. He suggested that myocardial sarcoid was probably underdiagnosed and was not a rare condition. In 1984, he also suggested that sarcoidosis was frequently overlooked until sudden death occurs, often in relatively young people, 25-54 years of age. In 1976, Matsui, et al., reported in a Japanese population on 72 individuals with sarcoidosis at autopsy. Fifty-eight percent of these individuals died because of myocardial involvement. Most of these deaths were sudden and the diagnosis was generally not suspected during life. In addition, myocardial involvement was apparently a late complication and was not predicted by progressive pulmonary involvement. In 1977, Roberts et al., reported on 113 patients found to have myocardial sarcoidosos at autopsy. Seventy-nine percent had cardiac dysfunction due to myocardial involvement, 67 percent experienced sudden death, and 23 percent developed congestive heart failure. Most patients with myocardial sarcoid presented initially with cardiac symptoms and most had little or no evidence of other organ involvement. In 16 percent sudden death was the initial manifestation of sarcoidosos. In view of the possible catastrophic consequences of sudden unexpected death

or sudden incapacitation of a military aviator, the United States Air Force (USAF) became concerned about the implication of myocardial sarcoidosis. Prior to 1978, all USAF flyers with sarcoidosis were evaluated at the local flight surgeon's office. After they became stable and the findings of sarcoid resolved, they were returned to flying duties with a local waiver. The details of the local evaluation were not prescribed by protocol and were based solely on the judgment of the local physician. In 1978, the USAF initiated the sarcoidosis study group. This program was initiated to solve 2 basic problems. First clinical studies indicated that a more thorough evaluation was required to examine the possibility that an individual with a history of pulmonary sarcoidosis may have asymptomatic butsignificant myocardial granulomas. This program also provided a mechanism for recurrent periodic evaluations to ensure the aviator's continued fitness for flying. The second objective of the sarcoid study group was to perform these evaluations in a systematic fashion with periodic review to determine the outcome of individuals with a history of sarcoidosis to insure that the prognosis of this grop was consistent with continued flying duties. Author

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THE AEROMEDICAL RISK ASSOCIATED WITH ASYMPTOMATIC CHOLELITHIASIS IN USAF PILOTS AND NAVIGATORS
G. W. SABOE, J. W. SLAUSON, R. JOHNSON, and T. H. LOECKER *In* AGARD, The Clinical Basis for Aeromedical Decision Making 6 p (SEE N95-19413 05-52) Sep. 1994
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The USAF aeromedical policy regarding incidentially discovered, asymptomatic cholelithiasis requires the aircrew to undergo cholecystectomy prior to being considered for return to flying duties. The merit of continuing this USAF policy was evaluated at the request of the USAF Surgeon General. A review of the medical literature predicted a 1 percent to 4 percent annual event rate of acute cholecystitis in individuals with previous asymptomatic cholelithiasis. The prevalence of asymptomatic cholelithiasis in USAF pilots and navigators was determined to be 2 percent to 3 percent, based on data acquired at the Ellingson Aerospace Medicine Consultation Service (ACS). Of 11.685 pilots and navigators evaluated at the ACS, 0.7 percent ($n = 880$) were diagnosed with cholelithiasis or previous cholecystectomy. Between 1972 to 1992, 16,232 man years of pilot and navigator exposure to asymptomatic cholelithiasis was estimated to have occurred; however, only 50 cases with a diagnosis of cholecystectomy or cholelithiasis were reported in the USAF Surgeon General waiver file. Mortality and morbidity associated with cholecystectomy by either open or laparoscopic technique were reported as 0.2 percent and 5 percent, respectively. Using 1994 USAF pilot and navigator manpower data and the worse case scenario of a 0.7 percent occurrence for the onset of acute symptoms associated with previously asymptomatic cholelithiasis, up to five aircrew would be expected to experience acute symptomatology at some time during 1994. However, if every pilot and navigator flew 200 to 1,000 flying hours during 1994, 0.1 to 0.6 individuals, or essentially none, would be predicted to experience acute symptoms related to gallstones inflight. The natural history of cholelithiasis in USAF pilots and navigators is more favorable than suggested by the clinical literature. The inflight risk of experiencing acute symptoms associated with previously asymptomatic cholelithiasis is essentially nonexistent in USAF aircrew. Author

N95-19440# Centro de Instruccion de Medicina Aeroespatial, Madrid (Spain).
CLINICAL BASIS FOR AEROMEDICAL DECISIONS IN AIRCREW HIV POSITIVE
JOSE A. AZOFRA, FRANCISCO RIOS, JUAN J. CANTON, PATRICK P. MILES, CARLOS VELASCO, and V. VELAMAZAN *In* AGARD, The Clinical Basis for Aeromedical Decision Making 3 p (SEE N95-19413 05-52) Sep. 1994
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There has been appropriate concern regarding HIV infection and its effect on aviation safety. Among reasons cited is the consideration that the nervous system is involved early in HIV infection and that dementia in its early stages may be subtle and difficult to detect, on opinion not currently supported by the medical literature. Others have felt that seropositivity alone did not constitute an unacceptable risk to aviation safety, suggesting that other criteria be used, such as the development of AIDS related symptoms, or laboratory abnormalities, prior to grounding a flyer. Discussion and controversy will continue in this area until specific studies of asymptomatic seropositive individuals' performance in real and simulated flying environments are carried out by the aeromedical community. As the prevalence of this disease continues to grow exponentially in the general population the answers to these questions will become increasingly more important. Author

N95-19441# Aerospace Medical Research Labs., Brooks AFB, TX. Ophthalmology Branch.
COLOR VISION ISSUES IN MODERN MILITARY AVIATION OR THE SEARCH FOR THE ABOMINABLE CONEMAN
DOUGLAS J. IVAN, J. TERRY YATES, THOMAS J. TREDICI, and JOHN M. GOOCH *In* AGARD, The Clinical Basis for Aeromedical Decision Making 17 p (SEE N95-19413 05-52) Sep. 1994
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Visual information provided to the modern military aircrew member accounts for the preponderance of data contributing to situational awareness. Although long recognized as a critical factor in aviation, as a result of advancing technological developments, color vision is emerging as an ever-increasing critical requirement in modern and future cockpits. Despite that premise, the modern battlefield is characterized by a vast array of technological weaponry that increases the threat to the visual system and dictates effective countermeasures that compromise visual performance in general and color perception in specific. This paper will review the aeromedical basis of color testing developments and issues that effect aeromedical decisions in color standards and performance as they relate to the modern military aircrew member. It will include an update on color vision issues raised by protective equipment such as selective waveband filters that include sunglass materials and laser protective eyewear/visors. Color-related aircraft accident issues will be addressed. Author

N95-19442# Aerospace Medical Research Labs., Brooks AFB, TX. Ophthalmology Branch.
PHOTOREFRACTIVE KERATECTOMY (PRK) IN THE MILITARY AVIATOR: AN AEROMEDICAL EXPOSE
DOUGLAS J. IVAN *In* AGARD, The Clinical Basis for Aeromedical Decision Making 18 p (SEE N95-19413 05-52) Sep. 1994
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Refractive surgery to correct rehabilitate refractive errors of the eye continues to evolve at a significant pace and is here to stay. The surgical manipulation of the cornea by carefully planned incisions, as in radial keratotomy, represented the first technological procedure to evolve for the correction of ametropia and is an area of continued active development and improvement. More recently, photorefractive keratectomy (PRK) using laser technology to ablate and recon-tour the corneal surface has emerged as a viable modality. This paper explores the aeromedical factors surrounding this new revolutionary procedure and discusses the issues relevant to evaluating its applicability to the modern aviator as well as reviewing results of the latest clinical trials currently in progress. The goal is to provide the aeromedical community with the fundamental information required to formulate aeromedical decision- and policy-making in regard to a new procedure that is certain to have tremendous impact on future aircrew candidates. Author

N95-19443# Institute of Aviation Medicine, Prague (Czechoslovakia).
MEDICATION IN THE COURSE OF ACTIVE FLYING DUTY
M. RADA, A. DVORAK, and J. SULC *In* AGARD, The Clinical Basis for Aeromedical Decision Making 8 p (SEE N95-19413 05-52) Sep. 1994
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The Czech Institute of Aviation Medicine deals with the practice of medication of airmen without the prohibition of active flying over 25 years. The experience with medical treatment of 420 airmen during the 1982-1993 period is presented in details. Main reason for employment of this policy follows from the successful management of initial stages of primary hypertension as well as of other health disturbances. Hypertension counts for 57.9 percent of all cases liable to medication, being most often started in the second half of the fifth and first half of the sixth decade. Mean duration of medication took 3, 4 years leading to the overall

prolongation of active flying for 2, 9 years. A combination of two antihypertensive agents, viz. the diuretic and the beta-blocking agent appears to be the most effective method. Among other frequently applied pharmaceuticals hypolipidaemic and hepato-protective agents along with vitamin compound remedies should be included. The introduction of medication must precede a thorough medical and psychological examination, repeated prior to waivered certification. Regular observation performed by a flight surgeon or a licensed aeromedical examiner is mandatory. With observance of responsible policy the preservation of an airman in active duty despite his/her medication brings significant economic as well as social benefits without the flight safety impairment. Author

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BEHAVIORAL SCIENCES

Includes psychological factors; individual and group behavior; crew training and evaluation; and psychiatric research.

N93-19660# Gulhane Skeri Tip Akademisi, Eskisehir (Turkey). Aerospace Medical Center.
ASSESSMENT OF MORALE IN TURKISH AIR FORCE PILOTS WITH TWO CLINICAL PSYCHOLOGICAL TESTS
MUZAFFER CETINGUC, SAIT DEGER, and O. YALUG *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 4 p (SEE N93-19653 06-03) Sep. 1992
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In popular understanding good morale is equal to the perception of well being, lack of distress and absence of anxiety and depression. Actually the term morale is related to anxiety and depression. The rational of this survey is to assess numerically stress levels by using anxiety and depression scores. 345 active duty Turkish Air Force (TuAF) pilots and 70 non-flying air force officers as control group, have been taken into this study. 'State Trait Personality Inventory' (STPI-Spielberger) and 'Zung Depression Scale' (ZDS) were applied to both groups in 1988. As an unexpected result, the flyer group has reflected lower scores than the non-flyers. Different explanations are available but they are most likely to be related to high motivation and job satisfaction as well as ego strengths of flyers. These factors can elevate the ability to cope with stressful conditions. Author

N93-19679# Air Force Human Resources Lab., Brooks AFB, TX.
EPIDEMIOLOGY OF UNITED STATES AIR FORCE SPATIAL DISORIENTATION ACCIDENTS: 1990-1991
TERENCE J. LYONS, WILLIAM R. ERCOLINE, JAMES E. FREEMAN, and KENT K. GILLINGHAM *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 11 p (SEE N93-19653 06-03) Sep. 1992
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Spatial disorientation (SD) continues to be a contributing factor to a fairly constant proportion of military aircraft accidents. The United States Air Force (USAF) fielded a new accident investigation reporting form in July 1989, which for the first time specified SD Type 1, Type 2, and Type 3 as possible causes of aircraft accidents. Of a total of 91 major accidents that occurred over the 2-year period beginning in October 1989, SD contributed significantly to 13 (14 percent). Although this percentage is higher than that reported in previous studies, the actual rate of SD accidents per 100,000 flying hours (.1843) is lower than previously reported. Type 1 SD was the cause of all 13 accidents; 9 of the 13 were fatal; 6 occurred in night or instrument meteorological conditions (IMC) conditions; and 11 involved cockpit attention problems, such as inattention, distraction, or channelized attention. Pilot inexperience did not appear to be a factor: average total flying time for the 13 pilots was 1,687 hours. Coding for SD on accident investigation reporting forms was not consistent. There were both individual differences between flight surgeons and pilots, and trends in reporting overtime. There is, however, a consensus that SD represents a major problem in military aviation. A scientific approach to this important problem would be facilitated if agreement could be reached on definitional and semantic issues. Author

N93-19680# Army Air Corps, Stockbridge (England).
DISORIENTATION AND FLIGHT SAFETY: A SURVEY OF UK ARMY AIRCREW
S. J. DURNFORD *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 14 p (SEE N93-19653 06-03) Sep. 1992
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This paper reports the finding of a questionnaire survey intended to gather disorientation. 440 UK Army aircrew were targeted and the response rate was 79 percent. The survey confirmed the high incidence of disorientation (24 percent of aircrew had suffered at least one episode severe enough to have put flight safety at risk at some point during their flying career and 6 percent had suffered such an episode in the previous 4 months). Only 10 percent had never suffered any disorientation. I.I.C.

N93-19681# Sextant Avionique, Saint Medard en Jalles (France).
OTOLITHIC ILLUSIONS ON TAKEOFF AND VISUAL INFORMATION: REFLECTIONS IN CONNECTION WITH AN AIR ACCIDENT CASE [ILLUSIONS OTOLITHIQUES AU DECOLLAGE ET INFORMATIONS VISUELLES: REFLEXIONS A PROPOS D'UN CAS D'ACCIDENT AERIEN]
A. LEGER, C. MARTIN, and R. PARUS *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

Otolithic illusions on takeoff (takeoff illusions) have long been known as causes of air accidents. They originate in acceleration + Jx of the aircraft which, while adjusting to the gravity vector, produces an otolithic stimulation generating an excessive feeling of being pulled (somatogravic illusion). This type of illusion appears primarily when the visual references are insufficient (night takeoff, foggy environment). An air accident having led to the loss of a modern combat aircraft is reported. The circumstances and the various parameters of flight (accelerations Jx and Jz, speed, trajectory and altitude, actions of the pilot, etc.) are analyzed. From these data, the resulting otolithic stimulation undergone by the pilot during the flight was reconstituted. The evolution of this stimulation makes it possible to explain perfectly the actions carried out by the pilot, making this accident a typical example of takeoff illusion. The analysis of this air accident shows that the pilot never seemed to have used the visual attitude information presented by the head high visor in the aircraft. Beginning with these elements, a reflection of the visual information of the space orientation presented in the sights is carried out. It results in the consideration of various solutions likely to reduce the risks of confusion. The introduction of display systems connected to the head poses a certain number of new problems in this field, but also opens up interesting prospects. Author

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COGNITIVE FACTORS IN THE AIR EVENTS OF THE AIR FORCE DURING THE LAST DECADE [LES FACTEURS COGNITIFS DANS LES EVENEMENTS AERIENS DE L'ARMEE DE L'AIR AU COURS DE LA DERNIERE DECENNIE]
J. Y. GRAU, R. AMALBERTI, and J. P. MENU *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 6 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

Accident prevention has been a continuous concern since the early beginnings of aviation. Early efforts in prevention have been devoted to system reliability, then to physiological factors. Improvements in both these directions lead to consider cognitive factors as the main source of accidents. Prevention effort must take into account pilots' cognitive processes. In depth cognitive analysis of aircraft accidents serve to point out error mechanisms. Statistics complete this figure showing the respective occurrence frequency of these mechanisms, therefore orient the preventive actions. Such an approach, focused on the cognitive factors involves to define a specific analysis grid from psychological theories on human error. The elaborated grid is the basis to design a cognitive oriented data base. Author

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MEDICAL EVALUATION OF SPATIAL DISORIENTATION MISHAPS

A. RUPERT, F. E. GUEDRY, and J. CLARK *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 5 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

Spatial Disorientation (SD) is a leading human-factors cause of class A mishaps in all branches of the U.S. Armed Forces. Recently, several pilots who performed well under most flight conditions were referred to the Naval Aerospace Medical Research Laboratory (NAMRL) because of inability to fly under specific conditions conducive to SD. Most had been neurologically classified as normal using the presently available clinical tests. The pilots were then referred to NAMRL for assessment of vestibular function. Some of these pilots demonstrated perceptual anomalies in attitude perception that rendered them unable to fly safely under select combinations of acceleration and visual presentations. Although U.S. Navy pilot applicants are thoroughly assessed to meet visual and auditory standards, there are no specific screening tests for vestibular function. Thus, it is possible for members of the pilot community to possess reactions that under certain conditions will render them particularly susceptible to SD. In response to requests from clinicians, we have initiated the development of a Pensacola Vestibular Test Battery (PVTB) to assess aircrew referrals. The PVTB is being used to build a normative and pathological data base that will be incorporated into mathematical models that will inform the clinicians of the perceptual consequences of vestibular anomalies in the flight environment. The same computer-based models will be useful for aircraft design, pilot selection, and mishap investigation. Author

N93-19705# Hopital Ambroise Pare, Boulogne-Billancourt (France).

THE INFLUENCE OF INDIVIDUAL SENSIVITY TO STRESS ON THE BEHAVIOR (ATTITUDE AND PERFORMANCE) OF AVOIDANCE OF AN ACCIDENT [INFLUENCE DE LA SENSIBILITE INDIVIDUELLE AU STRESS SUR LE COMPORTEMENT (ATTITUDE ET PERFORMANCE) D'EVITEMENT D'ACCIDENT]

CLAIRE PETIT, ALAIN PRIEZ (Hopital Raymond Poincare, Garches, France), CLAUDE TARRIERE (Centre National de la Recherche Scientifique, Lyon, France), ANDRE DITTMAR (Centre National de la Recherche Scientifique, Lyon, France), and EVELYNE VERNET-MAURY *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 7 p (SEE N93-19653 06-03) Sep. 1992 In FRENCH

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The Department of Environmental Sciences of RENAULT studies the behavior of a broad sample of drivers (100 people of both sexes, of all ages and all driving experiences) implied in an accidental situation (simulation of an intersection between two roads). The goal is to analyze the way in which the driver of a car uses the device for anti-locking wheels or not, not only to slow down but also to carry out a lateral offset in order to avoid the obstacle. It appears that the sensitivity of the subjects to stress, evaluated by a physiological approach during the experiments but also by psychological tests carried out before and after the experiments, explains for a considerable portion the success or failure to avoid the obstacle. Author

N93-19709# Gulhane Skeri Tip Akademisi, Eskisehir (Turkey).

GREMLINS: A DOZEN HAZARDOUS THOUGHT AND BEHAVIOR PATTERNS AS RISK FACTORS

MUZAFFER CETINGUC *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 4 p (SEE N93-19653 06-03) Sep. 1992

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The term 'Gremlins' is known as fictitious ill-tempered spirits loved by children as comic strips and movie characters. During World War 2, it was an easy and unscientific way to throw blame on Gremlins which were considered responsible for unexplainable mechanical difficulties, as if a gin caused malfunctions in the aircraft. It was the gremlin, that diagnosis of pilots and engineers for mechanical malfunctions, that caused aircraft accidents during World War 2. Today they are nothing but puppets and movie characters. Reasons of accidents are explained by more scientific methods. Although modern technology presents materials providing safety in almost all conditions, accidents continue on faults rising from human beings. In this concept, it fits more to use gremlins as 'ill-temperness belonging human psychology that may cause risk'. Some certain personality variances effect the decision and judgement functions. These disorders reflected to thinking and behavior, sometimes may be leading reasons of accidents. I.I.C.

N94-23979# Pennsylvania State Univ., University Park, PA. Dept. of Psychology.

PERCEPTION IN FLIGHT: SHAPE AND MOTION PERCEPTION, SPACE PERCEPTION, SPATIAL ORIENTATION, AND VISUAL VESTIBULAR INTERACTION

HERSCHEL W. LEIBOWITZ *In* AGARD, Visual Problems in Night Operations 9 p (SEE N94-23976 06-54) May 1992

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Differences between the normal terrestrial and the flight environment are described which may lead to perceptual errors in flight. Specific examples involving the perception of shape and height are discussed as they may relate to nighttime landing accidents. The possible role of misperceived risk is suggested as a contributing factor. The mechanisms subserving motion perception and gaze stability are outlined briefly as the basis for understanding false sensations, illusory motion, spatial disorientation, and motion sickness. It is suggested that an appropriate countermeasure to perceptual errors in the nighttime flight environment is to inform flight crews of the mechanisms and mode of operation of the perceptual systems involved as the basis for understanding how they might misfunction. Derived from text

N94-23980# Centre d'Enseignement et de Recherches de Medecine Aeronautique, Paris (France). Dept. Ergonomie Aerospatiale.

MENTAL IMAGES [LES IMAGES MENTALES]

RENE AMALBERTI *In* AGARD, Visual Problems in Night Operations 10 p(SEE N94-23976 06-54) May 1992 In FRENCH

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The concept of mental images is paradoxically poorly linked to visual perception. It is related to the domain of mental representation, and thus is explained with reference to the field of cognitive psychology. This domain being relatively new for most of the listeners of this short course, basic concepts are didactically introduced. A framework model of cognitive activities is set up, introducing first the various memories, then focusing on mental representation processes. The specificites of mental representation are detailed (laconism, distorsion, parcimony, and task-oriented). Special emphasis is given to the mental representation theory of double coding: verbal and image coding and its relationship with activity. A last section describes how mental representation, especially mental image, could serve or impair night-flight activities. Author (revised)

N94-37261# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

VIRTUAL INTERFACES: RESEARCH AND APPLICATIONS [LES INTERFACES VIRTUELLES ENTRE RECHERCHE ET APPLICATIONS]

May 1994 186 p In ENGLISH and FRENCH Symposium held in Lisbon, Portugal, 18-22 Oct. 1993

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Recent advances in technologies for information display and sensing of human movements, combined with computer based models of natural and artificial environments, have led to the introduction of so-called virtual interfaces. Virtual interfaces offer increased flexibility and naturalness, so are considered for use in several domains including aviation, training, design, and simulation. Papers presented at this symposium considered issues of research and application in virtual interfaces broadly defined. Issues of technology integration for system development were considered separately from issues of movement monitoring or sensory display. Issues of human performance measurement were presented in the context of both research and application. For individual titles, see N94-37262 through N94-37281.

N94-37265# Centre d'Etudes de la Navigation Aerienne, Toulouse (France).

ASSISTANCE IN INSTRUCTION AND TRAINING OF AIR TRAFFIC CONTROLLERS [AIDE A LA FORMATION ET L'ENTRAINEMENT DES CONTROLEURS DE TRAFIC AERIEN]

F. MARQUE, T. LABARRERE, and F. NEEL *In* AGARD, Virtual Interfaces: Research and Applications 9 p (SEE N94-37261 12-53) May 1994 In FRENCH

(AGARD-CP-541) Copyright Avail: CASI HC A02/MF A02

Under the control of the Center d'Etudes de la Navigation Aerienne (CENA: Air Navigation Study Center), the 'SPEECH' project utilizes the complementary input of industries (STERIA ENGINEERING AND TELECOM, SEXTANT AVIONIQUE and VECSYS) and of a research center (LIMSI) in the study and creation of a tool that would assist in the instruction and training of air traffic controllers. Based on the concomitant use of voice interface (synthesis and identification of speech) and of a supervisory system monitoring the dialogue, the prototype is able to rely completely on the audio channel. A validation from the operators of IHM vocal concepts, makes it possible today to consider operational usage of 'SPEECH' within the training process of air traffic controllers. The structure and the various elements of 'SPEECH' are introduced before attempting to evaluate its possible future applications. Details on the methodology used, based on the study of natural language, are also included. Author

N94-37268# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.

CREATION OF A VIRTUAL WORLD TO STUDY HUMAN SPATIAL PERCEPTION DURING SUSTAINED ACCELERATION

TAMARA L. CHELETTE, ROBERT L. ESKEN, and ERIC J. MARTIN *In* AGARD, Virtual Interfaces: Research and Applications 9 p (SEE N94-37261 12-53) May 1994

(AGARD-CP-541) Copyright Avail: CASI HC A02/MF A02

The staff of the Combined Stress Branch has completed the integration of a system to allow quantitative measurement of perceived attitude while under sustained acceleration. Equipment involved included the computer control system of the Dynamic Environment simulator (DES), a computer generated graphics system, a virtual world helmet mounted display, and a tactile device for reporting attitude perception. The use of a new perceived attitude measurement system in this experiment required not only the technical achievement of the distributed system on the DES, but also required better parameter characterization and basic psychophysical performance studies. In addition, we recorded several confounds and issues concerning the use of a helmet mounted visual system for attitude information as well as head and neck support limitations of such a system. Experimental results include basic psychophysical accuracy and precision, evidence supporting the haptic system sensitivity to a G-excess illusion (even while the vestibular system is maintained at a constant position relative to the G vector), and modeling of pooled response that supports and quantifies the vestibular component of the G-excess illusion. Author

N94-37278# Army Aeromedical Research Lab., Fort Rucker, AL.

VISUAL ACCOMMODATION TO VIRTUAL IMAGE DISPLAYS WHEN KNOWLEDGE OF OBJECT DISTANCE CONFLICTS WITH OPTICAL DISTANCE

JOHN C. KOTULAK, STEPHEN E. MORSE, and ROGER W. WILEY *In* AGARD, Virtual Interfaces: Research and Applications 4 p (SEE N94-37261 12-53) May 1994

(AGARD-CP-541) Copyright Avail: CASI HC A01/MF A02

In virtual image displays, the image is typically at or near optical infinity, while the object may be at any distance. This can create a conflict between the known distance of a target and its optical distance. If accommodation is drawn to the known distance of the object rather than the optical distance of its image, considerable retinal image blur can result. To determine whether this actually occurs, we measured the accommodation of seven young adult subjects with a dynamic infrared optometer. The subjects viewed a collimated virtual image of a target monocularly through third generation night vision goggles (ANVIS). Although the target itself was positioned randomly at either 6.0, 1.0, 0.5, or 0.33 m from the observer, its image was maintained at infinity by compensatory adjustments of the ANVIS objective lens. The observer was aware fully of the actual distance of the target. A simulated clear starlight night sky condition was used in order to degrade image quality such that the accommodative feedback loop was semi-open, an intermediate state between the closed and open loop conditions of previous experiments. The results show that for some subjects, knowledge of object distance is a more powerful cue for accommodation that the image's optical distance; however, for the majority of subjects, this is not the case. The subjects who were susceptible to the knowledge of object distance cue reported severe blur when the object was nearby. We also found that these same subjects, i.e., the susceptible ones, tend to have a more proximal dark focus than those whose accommodation is not influenced by knowledge of object distance. The linkage between dark focus and susceptibility to proximal influences has not been previously demonstrated and needs to be explored further. Author

N95-12133# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

PSYCHOPHYSIOLOGICAL ASSESSMENT METHODS (INCLUDING A REGISTER OF PSYCHOPHYSIOLOGISTS ON MICROFICHES) [METHODES D'EVALUATION PSYCHOPHYSIOLOGIQUE (LISTE DE PSYCHOPHYSIOLOGUES INCLUSE SUR MICROFICHES)]

JOHN A. CALDWELL (Army Aeromedical Research Lab., Fort Rucker, AL.), GLENN F. WILSON, MUZAFFER CETINGUC, ANTHONY W. K. GAILLARD, ALEXANDER GUNDER, DIDIER LAGARDE, SCOTT MAKEIG, GRETE MYHRE, and NICOLA A. WRIGHT May 1994 157 p Original contains color illustrations

(AGARD-AR-324; ISBN-92-835-0747-9) Copyright Avail: CASI HC A08/MF A02

The study of human-centered operationally-relevant problems in aerospace and aviation research and development can be enhanced by the inclusion of psychophysiological techniques. By measuring physiological variables in conjunction with performance and subjective measures, a more thorough understanding about the processes underlying performance can be obtained. This report presents a summary of the general utility of psychophysiological assessments, the types of applied problems which can be addressed with these assessments, and the qualities of several psychophysiological techniques. In addition, safety and ethical considerations, guidelines for making determinations about the most appropriate research strategy, and three research examples are discussed. The report concludes with a series of appendixes which offer the reader information on how to collect and analyze each of the psychophysiological measures. This Advisory Report was sponsored by the Aerospace Medical Panel of the Advsiory Group for Aerospace Research and Development (AGARD). Author

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MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT

Includes human engineering; biotechnology; and space suits and protective clothing.

N93-19662# H. W. Structures Ltd., Pitsea (England).

OCCUPANT KINEMATICS SIMULATION OF THE KEGWORTH AIR ACCIDENT

R. HAIDAR and N. ROCK *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

The use of computer simulation in the investigation of the crash of Boeing 737-400 at Kegworth has highlighted the importance of the technique in aiding the accident and medical investigations. The analysis has shown the importance of adopting a full brace position for crash landing thus offering significant protection against injury. The major value of the study has shown that a unique and definitive estimation of the occupant kinematics and the effects on the crash victims are possible for an aircrash. Author

N93-19665# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Delft (Netherlands). TNO Crash-Safety Research Centre.
OCCUPANT SIMULATION AS AN ASPECT OF FLIGHT SAFETY RESEARCH
J. J. NIEBOER, J. WISMANS, and R. VERSCHUT *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 9 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04
In the field of flight safety research there is a growing interest for mathematical simulation of human response and injuries associated with survivable aircraft accidents. A mathematical tool can be very helpful to evaluate and improve on-board restraint systems or to assess the effectiveness of different seat designs. The passenger brace position, being a human factor, can be evaluated efficiently as well. MADYMO is a well accepted integrated multibody/finite element program for Crash Victim Simulation. Recently the two-dimensional version of MADYMO was successfully applied for reconstruction of seat and passenger behavior during the M1 Kegworth air accident. In this paper a brief description of MADYMO as well as three flight safety applications are presented. Special attention is given to the application concerning a dynamic seat test involving a 50th percentile Hybrid 2 dummy and a greater than P3/4 dummy, representing a nine-month-old child, seated in a child seat. The MADYMO model used for this application was validated on the basis of sled test results. It can be learned that MADYMO is capable of predicting passenger and seat response in an aircraft crash environment. A discussion on future developments in this field concludes this paper. Author

N93-19666# Arup (Ove) and Partners, London (England).
COMPUTER AIDED METHODS FOR SIMULATING OCCUPANT RESPONSE TO IMPACT USING OASYS DYNA3D
T. J. KEER, R. M. V. STURT, and B. D. WALKER *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 16 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A03/MF A04
Numerical simulation can play a key role in design for crashworthiness and accident investigation. This paper presents recent work in the development of occupant simulation techniques for the automotive industry, and describes how the same techniques may be applied to aircraft crashworthiness. Author

N93-19667# Applied Physics, Inc., Nanuet, NY.
DESIGN/DEVELOPMENT OF AN ENHANCED BIODYNAMIC MANIKIN
PAUL H. FRISCH and WILLIAM BOULAY *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 9 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04
This publication details the design and development of an enhanced manikin form incorporating all instrumentation and data acquisition capabilities to record and reconstruct the six degree of freedom response of the manikin. The manikin is designed to enhance biofidelity and provided a three dimensional biodynamic response, attempting to approximate that of the human. These objectives resulted in the implementation of an omnidirectional response flexible spine and pelvis assembly. Author

N93-19668# Simula, Inc., Phoenix, AZ.
IMPROVING MANIKIN BIOFIDELITY
CAROLINE VANINGEN-DUNN, MARVIN RICHARDS, and INTS KALEPS (Wright Research Development Center, Wright-Patterson AFB, OH.) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 14 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A03/MF A04
Two programs demonstrating the feasibility of improving the dynamic response of ejection system test manikins have been completed for the U.S. Air Force. The first program developed a manikin neck that has greater biofidelity during vertical impact conditions than currently available manikin necks. The second program developed manikin arms and legs with proper mass and mass moments of inertia to improve dynamic response. Both programs were conducted to support the development of the U.S. Air Force's Advanced Dynamic Anthropomorphic Manikin (ADAM). Author

N93-19669# Department of Transport (England). Transport Research Lab.
THE DESIGN AND USE OF AUTOMOTIVE CRASH TEST DUMMIES
A. K. ROBERTS *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04
Anthropomorphic crash test dummies have been used by the automotive industry for many years in order to develop safer road transport. Accident investigations have shown how vehicle design has improved, with the number and severity of road casualty injuries decreasing despite increased use of road transport. Several different types of dummies of differing levels of sophistication are used to approve vehicles to a number of different standards and regulations. Dummies are used either to approve restraint systems at the component level or in full vehicle impact tests. Various performance criteria must be met by anthropomorphic test dummies, and these criteria are discussed with reference to the interests of the vehicle designer, the biomechanical engineer and the legislative authority. The paper concentrates on the approach to dummy design used to develop the new European Side Impact Dummy EUROSID-1. The methodology used to develop certification techniques is described as well as the dummy itself. Techniques to calibrate a dummy in terms of predicting human injury risk are reviewed. The techniques described are common to all automotive crash test dummies and can be applied to the design and development of anthropomorphic dummies to be used in other disciplines. Author

N93-19670# Biokinetics and Associates Ltd., Ottawa (Ontario).
AN IMPROVED ANTHROPOMETRIC TEST DEVICE
TOM GIBSON, JAMES NEWMAN, JOHN W. ZELLNER (Dynamic Research, Inc., Torrance, CA.), and KENNETH D. WILEY (Dynamic Research, Inc., Torrance, CA.) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 7 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04
This paper reviews recent experience with a new test dummy intended principally for use in motorcycle crash testing. Modifications to the Hybrid 3 to better service this particular environment also makes the device potentially suitable in aicraft occupant crash protection assessment. This new ATD contains a 16-channel on-board data acquisition system, lower extremities that are capable of monitoring for leg and knee injuries, a more flexible lumbar spine, a penetration monitoring abdomen, a deformable thorax with improved motion sensing capabilities and a neck with improved flexion and extension bending response. The femur and tibial complex are constructed of frangible elements whose biomechanical responses are based on available cadaver data. The knee is designed with fusible links that fail at load levels commensurate with that of human knee ligaments. The test device has been used in full-scale crash tests as well as limited laboratory validation tests. This paper illustrates the potential of this injury monitoring device for aerospace applications as well as identifying areas of future work. Author

N93-19671# Royal Netherlands Air Force, Volkel (Netherlands). Inst. of Aviation Medicine.
THE APPLICATION OF HYBRID 3 DUMMY TO THE IMPACT ASSESSMENT OF A FREE-FALL LIFEBOAT
D. H. GLAISTER, P. J. WAUGH, and L. NEIL *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 6 p (SEE N93-19653 06-03) Sep. 1992
(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04
A requirement to monitor occupant forces during the launch of a free-fall lifeboat has led to the definition of a transportable instrumented dummy and data-acquisition system. Good quality data have been recorded during 21 free-falls from which advice has been given concerning the acceptability of launch forces for both injured and non-injured personnel. Head restraint is not considered in the International Maritime Organization's current assessment criteria for free-fall lifeboats, but was shown to have a pronounced effect on head and neck forces, with significant overshoots being seen when no restraint was available. It is concluded that the dummy and data-acquisition system developed for these trials offers a valid means for assessing impact forces

and injury risk in novel impact environments such as the launch of a free-fall lifeboat. Author

N93-19672# New Orleans Univ., LA. Naval Biodynamics Lab.

A NEW INSTRUMENTATION SYSTEM FOR MEASURING THE DYNAMIC RESPONSE OF THE HUMAN HEAD/NECK DURING IMPACT ACCELERATION

M. S. WEISS, G. C. WILLEMS, S. J. GUCCIONE, JR., C. J. MUGNIER, and M. E. PITTMAN *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 6 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

Recently developed angular motion sensors, based on the laws of magnetohydrodynamics, have potential application in biodynamic research. These sensors were tested on the Naval Biodynamics Laboratory's (NBDL) vertical accelerator, using the Hybrid 3 manikin as the test subject. The sensors were used to measure the manikin's head motion in three dimensions. Experiments were conducted at impact levels up to 13g in the vertical (+Z) direction. Data was collected using both the new sensors and the standard NBDL package of nine linear accelerometers. A new method for obtaining initial position and orientation information using still photogrammetry was also evaluated. The analyses of the tests show that the new sensor and photogrammetry system compared well with the nine accelerometer array and the direct photographic measurement of displacement. Comparisons were made between measurements of acceleration, velocity and displacement. The new system yielded equivalent and, in some instances, more accurate results. This study extends the results of previous preliminary testing and confirms the value of the new system as a simpler, more accurate and portable replacement for the old one. Author

N93-19699# Spanish Air Force, Talavera AFB (Spain). Flight Surgeon.

AN EPIDEMIOLOGICAL STUDY IN SAF'S PILOTS EJECTIONS

J. L. GARCIA ALCON, M. R. DURAN TEJEDA (Extremadura Univ., Badajoz, Spain), and J. M. MORENO VAZQUEZ (Extremadura Univ., Badajoz, Spain) *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 8 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A02/MF A04

Aircraft escape systems - the ejection seat - have saved a lot of lives, however they often have several secondary problems. First, the physical injuries directly produced by the ejection itself; and secondly, the psychological alterations caused by the fact of suffering from an aircraft accident. This study has been made to get more data on ejections raised in some Spanish Air Force pilots in order to correct the possible mistakes in further ejections. The most remarkable results are: First, the importance of performing the ejection within the safety limits of the seat, and with a very good sitting posture, to minimize possible injuries. Secondly, the necessity for both ejection seat simulator and parachute training of pilots since most injuries are generated when the pilot has a wrong sitting posture and when he lands on the ground. And finally, the quick incorporation to flying duties as soon as the ejected pilot accomplished his total recovery. Author

N93-19704# Institute of Aviation Medicine, Oslo (Norway).

THE NEXT GENERATION FEMALE IN COCKPIT: DO WE NEED A NEW APPROACH TO COCKPIT RESOURCE MANAGEMENT (CRM)?

G. MYHRE and J. E. JANSEN *In* AGARD, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques 3 p (SEE N93-19653 06-03) Sep. 1992

(AGARD-CP-532) Copyright Avail: CASI HC A01/MF A04

Several aviation accidents are caused by inadequate or misinterpreted communication within the crew or between cockpit and ATC. The present pilot training put more highlight on personality attitudes that favor crew coordination in addition to technical expertise than earlier days. This may imply that cultural differences more easily will emerge and have to be taken into training considerations instead of more or less ignoring them as was possible when the operational performance proficiency was all that really mattered for the professional pilot. With more females entering pilot training one should accept that the two sexes emerge from different training strategies, especially within crew resource management training may work more effectively than it has up till now. I.I.C.

N93-19757# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.

ADVANCED AIRCRAFT INTERFACES: THE MACHINE SIDE OF THE MAN-MACHINE INTERFACE [LES INTERFACES SUR LES AVIONS DE POINTE: L'ASPECT MACHINE DE L'INTERFACE HOMME-MACHINE]

Oct. 1992 296 p In ENGLISH and FRENCH Symposium held in Madrid, Spain, 18-22 May 1992

(AGARD-CP-521; ISBN-92-835-0689-8) Copyright Avail: CASI HC A13/MF A03

This Symposium explored the use of three of man's senses (sight, hearing, touch) to improve the man-machine interface in the cockpit. The seven sessions included Defining Concepts and Design Issues, Maintenance for Advanced Cockpit Systems, Panoramic and Virtual Cockpits, Helmet Mounted Displays, Voice Technology, System Design Concepts and Tools, and finally Device Technologies. As the demands placed upon the aircrew by the modern battlefield continue to increase, this Symposium attempted to effectively blend the technologies available to decrease the workload. For individual titles, see N93-19758 through N93-19785.

N93-19758# Technische Univ., Twente (Netherlands). Computer Vision Lab.

ENGINEERING THE VISIBILITY OF SMALL FEATURES ON ELECTRONIC FLIGHT DISPLAYS

D. BOSMAN *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 7 p (SEE N93-19757 06-54) Oct. 1992

(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

The applications and limitations of high resolution afforded by modern display technologies are discussed, in relation to the properties of the human visual system; and how much 'engineering' may become possible early in the design phase by the use of model(s) of the 'visual system - technology interface' (VSTI). Display technology models provide good predictions of the distributions of luminance, color, and contrast under specified driving and environmental conditions. Coupled to suitable vision models, estimates of visibility of pattern details can be made. In VSTI models, the beholder of the imagery is regarded as a detector responding to displayed pattern with 'yes', 'no', or even be allowed fuzzy and false responses. Some conclusions are given concerning design of pattern details in imagery, given the characteristics of the display and of the observer. Author

N93-19759# Naval Air Warfare Center, China Lake, CA. Aircraft Weapons Integration Dept.

HUMAN FACTORS PROBLEMS FOR AIRCREW-AIRCRAFT INTERFACES: WHERE SHOULD WE FOCUS OUR EFFORTS?

JUDITH H. LIND and CAROL G. BURGE *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 12 p (SEE N93-19757 06-54) Oct. 1992

(AGARD-CP-521) Copyright Avail: CASI HC A03/MF A03

Twenty eight problem areas where human factors engineers lack the information needed for development of crewstations for advanced military fighter and attack aircraft are identified and discussed. Emphasis is on naval air missions projected during the early 21st century against land and sea-surface targets. The 28 problem areas are based on the functions that the crews must carry out for successful mission accomplishment. Human capabilities and limitations documented in the human factors literature that relate to these aircrew functions were used to define the problem areas. The goal is to ensure that aircrew performance will be satisfactory for anticipated air missions. The 28 problem areas are grouped into nine human factors problem categories. For each category, the human factors knowledge and man-machine interface engineering capabilities that should be extended during this decade are noted. The human factors problem categories are (1) physical and physiological stress, (2) vigilance and aircrew alerting, (3) individual differences, (4) information integration, (5) visual displays for various missions, (6) mission management, (7) decision support, (8) automation, and (9) system design and evaluation. Author

N93-19760# Telefunken System Technik G.m.b.H., Wedel (Germany). Aircraft Equipment.
ADVANCED COCKPIT-MISSION AND IMAGE MANAGEMENT
JUERGEN STRUCK, ed. *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 15 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A03/MF A03

Modern cockpit designs require new modular architectures for mission and image-management with regards to hardware and software aspects. The main task is the collection of aircraft specific data using the appropriate data management, the transformation of such data to graphical images with the appropriate logical image management, the generation of physical graphical images on several image devices by physical image management and the conversion and combination/mixing of physical graphical data with the data, created by external video sensors using video management. Finally the video-data has to be presented on several devices, like head down-, head up-, and helmet mounted displays. The main goal for us as basic system supplier is to give the application programmer an abstract high-level interface for all these functions. This is to be done and is specially supported by the program language Ada, which is the required language for military and civil aircraft applications. The system described herein was developed for the German experimental helicopter program AVT and two special applications for the X31A experimental aircraft. Author

N93-19761# British Aerospace Aircraft Group, Brough (England). Kingston Military Aircraft Ltd.
AIRCREW ACCEPTANCE OF AUTOMATION IN THE COCKPIT
MARK HICKS and IAN ROSS (British Aerospace Aircraft Group, Kingston-upon-Thames, England) *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 5 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A01/MF A03

The concept of human-electronic co-operation in the cockpit is synonymous with that of a team. Whether or not team members interact effectively will rely largely upon the pilot's acceptance of his electronic team mate. This paper reports on the attitudes of eight British Aerospace test pilots towards the future of such co-operation. Particular emphasis is laid upon the factors of system function, task allocation, and trust. Pilots opinions are examined against a schema of 'Operational Relationships', recently proposed in the literature. Author

N93-19762# Rome Lab., Griffiss AFB, NY. Systems Reliability Div.
TIME STRESS MEASUREMENT DEVICES FOR ENHANCEMENT OF ONBOARD BIT PERFORMANCE
LEONARD J. POPYACK, MARK E. MCCALLUM, and JAMES A. COLLINS *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 6 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

An important aspect of a pilots situational awareness is the need for accurate real time information on the operational status of all aircraft systems. False and intermittent indications have been a problem with many of the built-in-test (BIT) functions in aircraft systems. These indications result in Retest OK (RTOK) and Cannot Duplicate (CND) maintenance events when the aircraft returns. These types of events account for 35 percent to 65 percent of the indicated faults in many Air Force avionics systems. Any false indications put an unnecessary and potentially fatal burden on the pilot during the operational scenario and also consume significant maintenance resources. Many of these false alarms and intermittent status indications are related to the environmental conditions present at the time of the indication. Time Stress Measurement Device (TSMD) technology offers a means of providing this crucial environmental information to the system's BIT. TSMD's are digital environmental measurement and recording devices in a microelectronic package which can be embedded into a system at the time of manufacture or on a retrofit basis. The information collected and provided by the TSMD can be provided in real time for the on-board BIT to try and discriminate between transient system performance anomalies and hard failures. Thus, only accurate performance status information is reported to the pilot. The paper describes the background of TSMD development, current state-of-the-art in TSMD hardware and software, current applications which address the enhancement of on-board BIT performance, and future thrusts in the TSMD area. Author

N93-19764# Air Force Wright Research and Development Center, Wright-Patterson AFB, OH. Advanced Technology Integration Office.
DEVELOPING VIRTUAL COCKPITS
WAYNE L. MARTIN *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 8 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

The motivation for development of virtual crew system technologies stems from the growing complexity of cockpit interfaces and the realization that humans are spatial beings who are much better equipped to process and control information if it bears a spatial and temporal relationship to the way the real world exists at the moment. The virtual cockpit will provide three-dimensioanl (3-D) spherical awareness, intuitive control interfaces, and automated assistance to the pilot. Three-dimensional visual and auditory information will be presented via the pilot's helmet, while tactile information may be presented through micro-stimulators within the pilot's glove, which are activated as a function of hand and/or finger position within the cockpit. The intent is to build a virtual cockpit that creates a representation of the look and feel of the real world, to the extent that the interaction with the display and control of information is as natural as possible. The notion of a virtual cockpit has been popularized in the 'Super Cockpit' concept. The Super Cockpit concept demands a functional integration of a broad range of advanced control, display, and avionic technologies. The successful marriage of the individual capabilities that each of these technologies represent demands an understanding and appreciation of the requirements for sensing, processing, and displaying information to provide the pilot the advantage of 3-D spatial/situational awareness throughout the mission. The multifaceted development issues associated with realization of the virtual cockpit are addressed. Author

N93-19765# Wright Research Development Center, Wright-Patterson AFB, OH. Wright Lab.
PANORAMIC COCKPIT DISPLAYS
DARREL G. HOPPER *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 25 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A03/MF A03

The great challenge of today's cockpit designers is to provide the 21st century pilot the necessary situation awareness to be effective in combat. This situation awareness is difficult to achieve because a pilot has to look at numerous dials and indicators, multiple small displays with different range scales and ownship locations, and distorted radar images. Today the pilot must fuse all information and be able to make immediate critical decisions in a combat environment. Part of the solution to this information overload problem is a panoramic agile-window display. The advantages of a large area display system were recently demonstrated in the Panoramic Cockpit Control and Display System research program. The principal objective result was a 45 percent increase in pilot combat effectiveness. The key to the implementation of the panoramic cockpit concept is a large area display together with a helmet-mounted equivalent of the present day head-up display. The large area head down system uses direct view or projected view to create an aggregate display area of 650-2000 sq cm. The status of cockpit displays is reviewed with an emphasis on hardware. Several technologies are being developed simultaneously and are analyzed here against requirements of our cockpit visions for new systems such as the F-22 and RAH-66, retrofit programs like the C-130/C-141, and advanced fighter and transport concepts. Author

N93-19766# Dassault-Breguet Aviation, Saint-Cloud (France).
FLIGHT ABOVE A VIRTUAL WORLD [VOL AU-DESSUS D'UN MONDE VIRTUEL]
P. LARROQUE and R. JOANNES *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 11 p (SEE N93-19757 06-54) Oct. 1992 In FRENCH
(AGARD-CP-521) Copyright Avail: CASI HC A03/MF A03

Research for stealth methods of low level penetration flight leads us to consider the use of terrain data bases which are

becoming more and more easily available. This is why the French Ministry of Defence has granted DASSAULT AVIATION a contract in the scope of the APIS Exploratory Program. The purpose of this study was to consider the use of terrain files for designing synthetic images intended for combat aircraft. The aim is to provide the pilot with pictures replacing direct sight on the outside world, thus helping him to conduct the flight by any weather or at night. The research for this new concept was supported by intensive software development on real time simulation tools. The latter permitted the proposal of different APIS representations for both head-up and head-level displays. The process followed during the elaboration of the images with the active participation of the French Officials is presented. We also give some examples of proposed pictures. At the end of the study these proposals were assessed by a team of ten military pilots, belonging either to flight test teams or coming from French Navy and Air Force. This evaluation has been carried out by the CERMA (French Aero-Medical Research Institute). However, many points are still to be examined: how to display these pictures onboard while managing safety and limiting costs and resources consumption at an affordable level.
Author

N93-19767# Delft Hydraulics Lab. (Netherlands). Delft Instruments Electro Optics.
A NEW CONCEPT FOR HELMET MOUNTED VISION
G. DEVOS, D. M. A. BROEKMANS, and R. P. SLEGTENHORST *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 10 p (SEE N93-19757 06-54) Oct. 1992
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Successful applications of holographic optical elements (HOE's) in the holographic night vision goggles have led to interesting developments of new concepts for helmet mounted vision systems. The present application of HOE's in night vision goggles is discussed, as well as a new concept of Helmet Mounted Vision Systems.
Author

N93-19769# Royal Aircraft Establishment, Farnborough (England). Flight Systems Dept.
THE MOD (UK) INTEGRATED HELMET TECHNICAL DEMONSTRATOR PROGRAMME
A. KARAVIS and T. H. SOUTHAM (Ministry of Defence, London, England) *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 10 p (SEE N93-19757 06-54) Oct. 1992
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As a result of progressively adding on capabilities to the basic protective flying helmet, present solutions to operational requirements result in barely acceptable flying helmet assemblies. The devices which provide these capabilities must all be compatible with each other, with the rest of the pilot's Aircrew Equipment Assembly (AEA), and with the aircraft. Often conflicting requirements result in compromises being made. Fundamental rules of optics cannot be changed, and in general, improved optical performance results in larger, heavier head-borne load. Heretofore, the solutions were engineered by several companies, each specializing in a particular discipline, resulting in the present 'add-on' philosophy. The UK MOD has taken the view that the time is appropriate for industry to adopt a more coordinated approach. The Integrated Helmet Technical Demonstrator Program (IHTDP) is aimed at encouraging a helmet to be designed from the outset with wide ranging capabilities, stimulating industry to form consortia to produce a truly integrated helmet. The background to the program and the requirements from the operators' point of view are discussed and the specification of requirements are described.
Author

N93-19770# Pilkington P.E. Ltd., Saint Asaph (Wales).
MULTI-FUNCTION VISOR
J. FOLEY and A. T. HEAD *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 3 p (SEE N93-19757 06-54) Oct. 1992
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A multitude of new roles are required for future aircrew visors. Large numbers of visors on a single helmet is not an acceptable solution. There is therefore a requirement for Multi-Function Visors which perform numerous roles. Many of the optical protective functions carry an unavoidable loss of visual transmittance. When these are combined, the overall visual transmittance may typically be 40 percent or lower. These functions therefore need to be combined on an outer Multi-Function Visor which the pilot can deploy at will. A permanent inner clear visor will provide all the mechanical protection and will also host the HMD combiner. A suite of outer MFV's may be required to cover all the combinations of laser threats in the visible, with the appropriate visor being selected for each mission.
Author

N93-19772# Lernout and Hauspie Speech Products N.V., Ypres (Belgium).
THE USE OF VOICE PROCESSING FOR SOME ASPECTS OF THE PILOT-VEHICLE-INTERFACE IN AN AIRCRAFT
FERNAND HOLLEVOET and CHRISTIAN J. WELLEKENS *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 7 p (SEE N93-19757 06-54) Oct. 1992
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The challenges that lie in the development and design of a pilot vehicle interface (PVI), both in the basic voice processing technologies as in the robustness requirements of the system, due to the peculiar circumstances in which it has to be used, are described. Furthermore, we will focus on the state of the art, and on the results of the current R&D efforts within Lernout and Hauspie Speech Products on both the recognizer itself as well as its robustness, and also the hardware implementation. At the end, we will dip into the future and look at the continuing R&D efforts both to enhance the available algorithms and to undertake new basic efforts in the area of application.
Author

N93-19773# Sextant Avionique, Valence (France).
MULTIMODAL DIALOG SYSTEM FOR FUTURE COCKPITS [SYSTEME DE DIALOGUE MULTIMODAL POUR COCKPITS FUTURS]
J.-N. PERBET, J.-J. FAVOT, and B. BARBIER *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 3 p (SEE N93-19757 06-54) Oct. 1992 In FRENCH
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The display devices of the future will call upon multimedia systems allowing a multimode dialogue between the man and the system. We describe the concept of a large interactive screen, built around an image wall in the instrument panel and an assembly of the means of dialog used simultaneously. It will make it possible to reduce the workload of the pilot by an optimization of the dialogue with the system while using, among other things, an intelligent dialogue assisting device. Many studies have been carried out on the isolated use of input-output devices (keyboard, mouse, handle, vocal reconnaissance...), but none presents a global solution of the multimode dialogue in the cockpit. We thus developed and implemented an experimental device to study man-system interactions using the eye, the hand, and the voice.
Author

N93-19774# Defence and Civil Inst. of Environmental Medicine, North York (Ontario).
PRINCIPLES FOR INTEGRATING VOICE I/O IN A COMPLEX INTERFACE
M. M. TAYLOR and D. A. WAUGH (Andyne Computing Ltd., Kingston, Ontario) *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 14 p (SEE N93-19757 06-54) Oct. 1992
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The integration of voice into a complex interface like that between a pilot and an aircraft is not trivial. We try to address some of the factors affecting the use and integration of voice in human-machine interfaces. We describe general principles for merging different kinds of human-machine interaction, and apply them to voice interaction in the cockpit. We do this despite published opinion that psychological principles cannot be applied in the design of human-computer interaction. The theory of Layered Protocols (LP) is introduced in context of the more general Perceptual Control Theory of behavior (PCT). LP theory provides a model for describing interaction between complex partners based on a layered structure of protocols that differ in levels of abstraction. The proper use of feedback is fundamental to both LP and PCT. Voice interaction is useful mainly for the control of tasks requiring discrete information. Failure of voice recognition systems is often caused by inappropriate feedback. Providing feedback and forcing

correction word by word may increase the mental load on a user, often leading to instability in the interaction. Such inefficient, and often frustrating, use of voice interaction can often be overcome through the use of feedback at higher, more abstract, layers of interaction. Successful adoption of voice interaction depends on allocating the appropriate tasks of communication to the voice protocol, the dynamic modeling of the partner, and the use of higher level protocols to help control potential instability. Author

N93-19775# Sextant Avionique, Valence (France).
G-LOAD EFFECTS AND EFFICIENT ACOUSTIC PARAMETERS FOR ROBUST SPEAKER RECOGNITION
CH. GULLI, D. PASTOR, A. LEGER, P. B. SANDOR, J. M. CLERE (Centre d'Essais en Vol, Bretigny-Air, France), and P. GRATEAU (Centre d'Essais en Vol, Bretigny-Air, France) *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 14 p (SEE N93-19757 06-54) Oct. 1992
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Acoustic features of the speech production with G-load effects were found from the computer signal analysis. Their correlates with physiological features will permit an interpretation of the variability of formant and pitch shifts. The pilot study experiments were conducted by SEXTANT and the LAMAS (Laboratoire de Medecine aerospatiale). Six subjects participated in the experiment. Their mean age was 30 years. A series of experiments in centrifuge environment were performed as part of a research program. A specific vocabulary was made for the first investigation with speakers in centrifuge. Comparison of spectrographic analysis and wavelet decomposition have permitted to show a spectral pattern modification for recognition process. Due to the accuracy and limitations of the sonograph measurements, we developed multiresolution transforms. A window Fourier transform is better suited for analyzing signals where all patterns appear approximately at the same scale. The old multivariate statistical analysis, after the Bark's transformation, can produce a good projection on the eigenvectors of the correlation matrix. The choice of the eigenvalues seems very easy for seeking the best representation of speech production. An interpretation of the mechanical effects due to the acceleration can be shown with analysis tools. We observed, in agreement with acoustic multi-resolution analyses, that producing speech in G-load conditions can increase energy, pitch, and formant frequency locations. The influence of the breathing on some parameters is noticeable. The last section discusses the incidence of these results on the robust speech recognizer for military cockpit environment. Author

N93-19776# Naval Air Warfare Center, China Lake, CA. Weapons Div.
A SYSTEMS APPROACH TO THE ADVANCED AIRCRAFT MAN-MACHINE INTERFACE
F. ARMOGIDA *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 13 p (SEE N93-19757 06-54) Oct. 1992
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Current thinking on the aircraft man-machine interface focuses primarily on the cockpit. My proposed approach will view the mission planning/mission rehearsal and the aircraft as an integral system that can perform three functions: (1) dynamically adjust itself to the particular pilot response in the planning/rehearsal stage, (2) adjust itself during the strike based upon the scenario encountered, and (3) adjust itself after each mission to enhance planning for follow-on missions. The objectives are to improve strike effectiveness and to shift portions of the pilot's work load from the attack to the planning phase of the strike. This concept can be implemented using existing and emergent technologies. Aircraft now coming on line are equipped with removable disks that are used to load mission specific data for the avionics and weapon systems (maps, ELINT files, route plans, navigation data, target coordinates, etc.). Mission planning systems are being configured not only to provide these data, but also to evaluate post flight data from flight recorders. Mission planning and rehearsal with the resulting aircraft mission data package will provide more inputs for the aircraft mission computer that will eventually fly the mission. Inter-aircraft computer communications will support adaptively optimizing the strike based upon the threat and target conditions encountered and the success of the strike to that point in time (adaptive mission control). Pilot intervention may only be required for aircraft-to-aircraft combat, freeing the pilot to attend to weapon aimpoint selection tasks (where the automatic systems have low confidence in their selections) or for unplanned contingencies. The mission planning/aircraft system, the notional aircraft avionics for adaptive mission control, and the implications for the man-machine interface are described. Author

N93-19777# Royal Air Force, Farnborough (England). Mission Management Aid Project.
MANAGEMENT OF AVIONICS DATA IN THE COCKPIT
E. J. LOVESEY *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 5 p (SEE N93-19757 06-54) Oct. 1992
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The rapid developments in avionics and the associated processing power now available in aircraft have produced cockpit systems which can quickly saturate the crew with information. Only by understanding man's capabilities and limitations will it be possible to design integrated avionics systems which match man's requirements and result in an effective man-machine combination. Only by paying great attention to management of the information flow between aircrew and avionics systems will it be possible to optimize the man-machine system in future combat aircraft. Examples of past problems and current developments in the management of data flow in the cockpit are given. Author

N93-19778# Smiths Industries Ltd., Bishops Cleeve (England).
MODEL-BASED REASONING APPLIED TO COCKPIT WARNING SYSTEMS
C. R. OVENDEN *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 7 p (SEE N93-19757 06-54) Oct. 1992
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With the advances in display technology and the increasing use of software control, more information in the modern commercial aircraft cockpit is available on request only instead of continually. Furthermore, the reduction in crew size has resulted in a reduction in the routine monitoring of system parameters. However, advances in sensory capability are enabling far more system parameters to be measured. The combination of these trends leads to the perception by the aircrew of an abrupt transition from normal operation to the need to deal with system malfunction. Work undertaken to maximize the use of available information in order to maintain the aircrew's awareness of the status of the aircraft's systems and to provide advice in the advent of malfunction or abnormality is outlined. The appropriate carrier of such information is the modern centralized cockpit warning systems. Author

N93-19779# British Aerospace Aircraft Group, Preston (England). Military Aircraft Div.
THE INTEGRATION OF ADVANCED COCKPIT AND SYSTEMS DESIGN
P. R. WILKINSON *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 9 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

The way in which typical operational scenarios that are representative of future conflict impact on the specification and design for man/machine performance is examined. Operational Requirements for aircraft to survive and deliver the goods in this context present a tremendous challenge to the Prime Weapon System Contractor. Military procurement agencies have long been striving to realize increased weapon system performance from dwindling resources. Thus current initiatives such as MANPRINT have been launched to change an equipment-oriented view of system development towards a broader view that considers hardware, software, and operator together as a system. It is argued that unless the piloting function and system integration tasks are considered as an integral part of the design process from day one, a less than optimum design will always result. It is recommended that a structured top-down design methodology be employed that translates Operational Requirements into piloting and system functions at one and the same time. An overview is given of use of just such a design process developed at BAe Warton, with particular reference to the European Fighter Aircraft (EFA) project. The various stages of the design process are explained and indications given of current progress of EFA. Emphasis is given to the tools and methods used to ensure that

a highly integrated system and advanced cockpit design are successfully achieved. Author

N93-19780# Elektronik-System G.m.b.H., Munich (Germany).
CVA, COCKPIT DESIGN AND DEVELOPMENT TOOL
CHRISTOPH WEBER *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 5 p (SEE N93-19757 06-54) Oct. 1992
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The conceptual design and development of a modern helicopter cockpit requires the consideration of ergonomic, operational, and technical aspects. New and additional technologies lead to a steady increase of data and workload, so that an essential task is to obtain an optimum layout of the 'Man-Machine-Interface' (MMI). For the performance of this task, MoD has charged ESG to generate a national Cockpit Design Tool CVA and to operate it in parallel with the TIGER development. Due to the national character of the CVA those tasks are primarily handled which concern the specific German portion of the TIGER program, e.g. the control and display system of the digital map generator, the helmet-mounted sight/display system, and the HF data link. These complex systems, however, cannot be investigated separately due to the multiple reciprocal actions with the remaining display and control systems, but have to be considered with the overall cockpit. Thus the CVA is the reproduction of a functioning 1:1 cockpit of the PAH2 version of the TIGER and is operated in close cooperation with the future user (pilot). It is a closed-loop simulator which enables the checking of important areas of the MMI not only in theory, but mainly under practical conditions long before a prototype of the new helicopter exists. Author

N93-19781# Naval Air Warfare Center, China Lake, CA. Aircraft Weapons Integration Dept.
MAN-MACHINE INTERFACE WITH SIMULATED AUTOMATIC TARGET RECOGNITION SYSTEMS
MARION P. KIBBE and EDWARD D. MCDOWELL *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 10 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

Growing numbers of targeting information sources in military cockpits have led to the development of automatic target recognition (ATR) systems. Since initially most ATR's will be used with an operator, a series of experiments was conducted to investigate aspects of the interface between the operator and the ATR. Two experiments are described which measured the speed and accuracy of ship identifications made by an operator using information from an imaging sensor and a simulated ATR. These measures were compared to performance of the unaided operator and to performance of the autonomous ATR. The accuracy of the ATR, the format of its output, and the quality and type of the sensor information was varied in the experiments. The results are discussed in terms of their implications for the design of the operator-ATR interface that will lead to satisfactory system performance. Author

N93-19782# Litton Systems (Canada) Ltd., Rexdale (Ontario).
THE ACTIVE-MATRIX LC HEAD-DOWN DISPLAY (AM-LCD): OPERATIONAL EXPERIENCE AND GROWTH POTENTIAL
J. F. FARRELL, J. C. PRINCE, and J. C. WRIGHT *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 11 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A03/MF A03

After a protracted development period, the active-matrix addressed liquid crystal light valve is finding increasing employment in a variety of head-down primary flight instrument applications. While the packaging efficiencies of such a flat panel technology are self-evident, many of its other attributes are also likely to have a profound impact upon crew station design. In order to successfully exploit the positive aspects of this technology, it is appropriate that the avionics systems architects benefit from the, albeit limited, current operational data base and develop a realistic understanding as to the limits and rate of advancement pertinent to this class of display device. The following paper is offered as an element in this information dissemination process from a source that has maintained a presence in the technology since 1984 and has participated in active-matrix liquid crystal display (AM-LCD) solutions for such diverse air-vechicle requirements as YF-23, LH, P-3C, and C-130. Author

N93-19784# Naval Air Warfare Center, China Lake, CA. Weapons Div.
ADAPTIVE AUTONOMOUS TARGET CUER
CHI-KIN LAM, DANIEL SEARLE, and WAYNE TANAKA *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 8 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

The Navy is exploring the use of an adaptive autonomous target cuer that is potentially more reliable than existing systems. Variations in the operational environment and target type are major factors that can degrade an autonomous sensor-based cuer performance. The solution presented here is to have several parallel algorithms for each functional component in our target cuer. Each algorithm is tuned to handle a particular situation. Based on certain indicator functions, a fuzzy logic expert system controller will select the most suitable algorithm and optimal parameters to process the sensor data. Although the proposed system is essentially comprised of conventional components such as image preprocessing, feature extraction, and correlation, it distinguishes itself because of its use of fuzzy logic in decision making and its adaptive nature. In designing an expert system, we will select the optimal set of indicator functions using the Taguchi process-control methodology. Preliminary results will be presented. Author

N93-19785# Eurocopter Deutschland G.m.b.H., Munich (Germany).
EQUIPMENT, MORE OR LESS READY TO BE USED IN HELICOPTERS
H. HELLMUTH and H.-D. V. BOEHM *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 6 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A02/MF A03

Examples of equipment taken from project studies and the specific boundary conditions for helicopters are discussed. Avionic equipment, sensors, displays, and controls are covered. Equipment and technologies ready to be used today and in the near future as well as equipment hardly usable are analyzed. Equipment specific characteristics and helicopter/cockpit integration specifics are covered. Author

N93-19917# Aeroplane and Armament Experimental Establishment, Boscombe Down (England).
HELICOPTER NIGHT VISION GOGGLE TESTING IN THE UNITED KINGDOM
MICHAEL R. SWALES and RANDALL W. CASON *In* AGARD, Flight Testing 12 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A03/MF A04

The ominous lethality of the modern battlefield necessitates the maximum exploitation of the cover afforded by darkness, making the ability to operate effectively at night a key factor in winning any major conflict. Unfortunately, the majority of the operational helicopter fleet was designed years ago with mainly daylight operations in mind. Converting these existing cockpits to an appropriate standard of night vision goggle (NVG) compatibility is no simple task. Quick fit, inexpensive fixes are rare and offer only limited value. The United Kingdom's Ministry of Defense (UK MOD) has learned this lesson well in recent years, having made large investments in both money and manpower to achieve an acceptable NVG standard of cockpit compatibility in the Sea King, Wessex, Lynx, Puma, Chinook, Gazelle, Scout and A109 helicopters. This paper will present an overview of helicopter NVG compatibility testing in the UK. A synopsis of the principles of image intensification will justify the logic behind various NVG modifications. An historic overview will then set the stage for the NVG cockpit developments, followed by a general discussion of some important compatibility issues. A review of the NVG operational assessments conducted in several different flight environments will conclude this discussion by presenting results peculiar to each environment. These wide-ranging assessments have provided the experience to develop a practical scientific approach to NVG cockpit compatibility testing which is offered in a summary of test methods. Author

N93-28850# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

COMBAT AUTOMATION FOR AIRBORNE WEAPON SYSTEMS: MAN/MACHINE INTERFACE TRENDS AND TECHNOLOGIES [L'AUTOMATISATION DU COMBAT AERIEN: TENDANCES ET TECHNOLOGIES POUR L'INTERFACE HOMME/MACHINE]

Apr. 1993 268 p Symposium held in Edinburgh, Scotland, 19-22 Oct. 1992

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Recent advances in combat automation technologies offer significant potential for improving overall mission effectiveness. Development of advanced situational awareness display concepts, parallel distributed computer architecture, and tactical information fusion techniques have paved the way for new operational capabilities and weapon system employment tactics. Harnessing these innovative technologies is critically dependent upon establishing an effective and intuitive pilot vehicle interface. The symposium addressed changing and possible future operational scenarios, advanced technology concepts, application issues and experimental development efforts and included sessions on: fusion, situation awareness, human capabilities and limitations, and design and evaluation of integrated systems. For individual titles, see N93-28851 through N93-28872.

N93-28853# Elliott-Automation Space and Advanced Military Systems Ltd., Camberley (United Kingdom). Aerospace Systems Div.

PILOT DECISION AIDING FOR WEAPON DELIVERY: A NOVEL APPROACH TO FIRE CONTROL CUEING USING PARALLEL COMPUTING

A. R. BUFFETT and R. M. WIMBUSH *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 18 p (SEE N93-28850 11-54) Apr. 1993

(AGARD-CP-520) Copyright Avail: CASI HC A03/MF A03

This paper describes the application of advanced technology, both hardware and software, to provide improved pilot Man-Machine Interface (MMI) automation for the central function of an airborne weapon system, namely weapon release. The specific scenario addressed is that of providing the pilot with decision aiding, in the form of firing cues, for the use of air-to-air missiles. The paper gives an overview of the need for automation/decision aiding in air-to-air missile fire control, by illustrating the way in which missile performance can vary greatly with the changes of engagement parameters which occur rapidly in an air-to-air combat scenario. The high pilot workload in this type of scenario, and the future requirement for multiple simultaneous missile firings, further support the need for automation to provide pilots with simple, processed, predictive data on which to base their firing decisions. Derived from text

N93-28855# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany). Inst. fuer Systemdynamik und Flugmechanik.

PILOT INTENT AND ERROR RECOGNITION AS PART OF A KNOWLEDGE BASED COCKPIT ASSISTANT

T. WITTIG and R. ONKEN *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 10 p (SEE N93-28850 11-54) Apr. 1993

(AGARD-CP-520) Copyright Avail: CASI HC A02/MF A03

A Pilot Intent and Error Recognition module as part of a knowledge based Cockpit Assistant System is presented, which is being developed at the University of the Armed Forces in Munich in cooperation with the Dornier company and implemented in a flight simulator. The system mainly supports the pilot crew with regard to the monitoring and planning task and provides assistance for a number of plan execution functions for the civil flight operation under Instrument Flight Rules. During the whole flight, the Pilot Intent and Error Recognition module monitors pilot activities and the flight status in order to detect deviations from the actual flight plan immediately. In this case, the current flight situation is evaluated, the pilot behavior is analyzed over a certain time period and by use of both pilot intent or error is recognized. Pilot errors lead to warning messages, and recognized pilot intent to a modification of the flight plan. In this paper, a short survey is given of the concept and the function of the Cockpit Assistant System. After that the structure of the Pilot Intent and Error Recognition will be described in detail. At the end, the integration of this module into the Cockpit Assistant System and the evaluation in a flight simulator are presented. Derived from text

N93-28856# Defence Research Agency, Bedford (England). Flight Dynamics and Simulation Div.

THE DESIGN AND DEVELOPMENT OF THE NEW RAF STANDARD HUD FORMAT

J. R. HALL *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 11 p (SEE N93-28850 11-54) Apr. 1993 Sponsored by RAF

(AGARD-CP-520) Copyright Avail: CASI HC A03/MF A03

In poor weather and on instruments, the safe piloting of an aircraft requires the display of basic flight information to the pilot in a manner that is instinctive, immediate, and unambiguous. Head-up display formats have singularly failed in this regard over the years and are known to be a contributing factor in many incidents involving lack of spatial awareness by the pilot. This paper describes the theory, experimental development, and flight proving of the DRA Fast-Jet HUD Format (FJF). This format has been designed to keep the pilot spatially aware under the most dynamic of flight maneuvers while retaining the flight-path information so necessary for mission effectiveness during normal tactical maneuvering and steady flight conditions. These include low level night operations with FLIR and NVGs and highly dynamic, hard maneuvering flight in poor weather or on instruments either at low level or in the air-to-air role. Derived from text

N93-28857# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany). Flight Simulation Dept.

SYMBOLOGY FOR HEAD UP AND HEAD DOWN APPLICATIONS FOR HIGHLY AGILE FIGHTER AIRCRAFT: TO IMPROVE SPATIAL AWARENESS, TRAJECTORY CONTROL, AND UNUSUAL ATTITUDE RECOVERY, PART 1

G. FISCHER and W. FUCHS *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 6 p (SEE N93-28850 11-54) Apr. 1993

(AGARD-CP-520) Copyright Avail: CASI HC A02/MF A03

The progressively increasing agility of modern fighter aircraft (a/c) with high onset and high sustained pitch and roll rates makes spatial orientation and awareness an even more demanding task for the operator. Pilots already complain about fast moving and twisting pitch bars in the HUD and the necessity to concentrate almost their entire attention on maintaining spatial orientation. Scaled and geared pitch bars relieved the problem to some extent but didn't solve it, at least according to our opinion. The above mentioned problems are aggravated with the introduction of advanced fighter a/c capable of even higher onset and angular rates and flying at higher angles of attack (AoA) or even in the post-stall regime where the actual flight path in space and the a/c attitude may deviate to a great extent. In order to overcome the problems mentioned above, a more stationary and more easily interpretable reference symbology, a circular arc segment, is used to indicate pitch (theta) or flight path angle (gamma), whereas the roll angle (phi) is given by the angular relation between a/c reference symbol and the center of the arc segment. Author (revised)

N93-28858# Rockwell International Corp., Los Angeles, CA.

VIRTUAL INTERFACE APPLICATIONS FOR AIRBORNE WEAPONS SYSTEMS

EMILY HOWARD *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 6 p (SEE N93-28850 11-54) Apr. 1993

(AGARD-CP-520) Copyright Avail: CASI HC A02/MF A03

This paper addresses a class of control and display technology that shall be referred to collectively as Virtual Interface (VI) technology. The contents of this paper are presented in three parts. Part 1 will describe what is meant by a 'virtual interface,' a suite of control and display technology being developed for future implementation in operational aircraft systems. The problem that will be discussed is how the transition process between development and operational status is particularly difficult for VI technology, given current applications. Part 2 will describe some new applications of VI technology, based upon several programs that utilize embedded simulation for operational test and evaluation and training purposes. A review of the benefits of VI technology shows promise for accelerating the transition process at least

toward these operational activities. Part 3 then will describe a new display concept, based on virtual interface technology, that was designed for one of these embedded simulation applications and conclude with a discussion of plans for future development. Author (revised)

N93-28859# General Dynamics Corp., Fort Worth, TX.
HEAD-STEERED SENSOR FLIGHT TEST RESULTS AND IMPLICATIONS
L. N. LYDICK *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 7 p (SEE N93-28850 11-54) Apr. 1993
(AGARD-CP-520) Copyright Avail: CASI HC A02/MF A03

A comprehensive flight test program of a head-steered FLIR/HMD night attack system was conducted between Aug. 1987 and Jan. 1990. Seventy-five development and demonstration F-16B flights were flown. Approximately 90 percent of the flights were conducted in night visual meteorological conditions. The remainder were conducted in daytime with the pilot's vision obscured by an opaque visor cover to simulate night and to study laser eye protection. Because the new FLIR/HMD systems were fully integrated with the F-16B fire control, navigation, communication, and display system, it was possible to achieve a considerable degree of tactical relevance in the tests. The night attack portion of the testing was a subset of a broader series of tests to explore advanced techniques for close air support (CAS). The work was industry sponsored by a number of corporations in a cooperative effort of about thirty million dollars. The tests and demonstrations culminated in operational test by (then) Tactical Air Command pilots at Nellis Air Force Base, Nevada, and Fort Hood, Texas. The night CAS systems evaluations were quite favorable and were planned for production until the remarkable end of the cold war reoriented (or perhaps gave pause to) planned introduction of the concepts to the fleet. In this paper, the author provides a summary overview of the mission, a description of the systems, the lessons learned, and some thoughts about future system requirements. Author (revised)

N93-28860# Defence Research Agency, Farnborough, Hampshire (England). Flight Systems Dept.
THE QUEST FOR AN INTEGRATED FLYING HELMET
A. KARAVIS and D. N. JARRETT *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 19 p (SEE N93-28850 11-54) Apr. 1993
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The addition of vision enhancement, display, and control functions to aviator's headgear is operationally attractive. The jets and helicopters that are currently under development call for headgear with a combination of these novel facilities. This paper reviews the recent history of such helmet systems, which demonstrate admirably the inventiveness of the design teams. However, there are attendant perceptual and operational concerns and the addition of extra components invariably compromises basic ergonomic qualities. A new design philosophy, which emphasizes functional integration rather than the incorporation of compatible sub-systems, is emerging. This will be assisted significantly when key optical and electro-optical technologies become mature. Author (revised)

N93-28861# Royal Air Force Inst. of Aviation Medicine, Farnborough (England). Biodynamics Div.
THE PHYSIOLOGICAL LIMITATIONS OF MAN IN THE HIGH G ENVIRONMENT
N. D. C. GREEN *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 8 p (SEE N93-28850 11-54) Apr. 1993
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The physiological limitations imposed upon man by the high-G environment are discussed, with particular reference to the cardiovascular, respiratory, and musculo-skeletal systems. Anti-G technology has been developed specifically for agile fighter aircraft, but it is apparent that if man is to have the capacity to tolerate any further increases in aircraft agility, a radically different approach to G protection is required. The most effective physiological solution is to change the orientation of the pilot such that his long axis is no longer in the plane of greatest acceleration, entailing major cockpit redesign. This and other solutions are examined, and their acceptability to aviators is considered. Author (revised)

N93-28862# British Aerospace Public Ltd. Co., Bristol (England). Research Centre.
OCULO-MOTOR RESPONSES AND VIRTUAL IMAGE DISPLAYS
G. K. EDGAR, C. NEARY, I. CRAIG, and J. C. D. POPE *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 8 p (SEE N93-28850 11-54) Apr. 1993
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Virtual image displays are likely to become more prominent in the cockpit, the most common examples being the head-up display (HUD) and, more recently, the helmet-mounted display (HMD). This paper describes a series of experiments highlighting some of the advantages and disadvantages of displays of this type. The first experiments demonstrate that introducing perceived depth differences into displays may improve eye-tracking performance. The second series of experiments illustrates some of the problems with virtual image displays; namely that the eyes may be inappropriately accommodated (focused) when using virtual image displays. The possible consequences of these problems are discussed. Author

N93-28863# Texas Technological Univ., Lubbock, TX. Dept. of Industrial Engineering.
HUMAN CAPABILITIES AND LIMITATIONS IN SITUATION AWARENESS
MICA R. ENDSLEY and CHERYL A. BOLSTAD (Monterey Technologies, Inc., Cary, NC.) *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 10 p (SEE N93-28850 11-54) Apr. 1993
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Achieving high situation awareness (SA) is a major goal in the design of aircraft systems. Efforts are currently underway by a number of individuals who are attempting to address this need through improvements in avionics system design, automation, and the pilot-vehicle interface (PVI). These efforts can be greatly enhanced through an understanding of human capabilities and limitations in achieving SA. This paper presents an identification of those factors which underlie basic human SA capabilities, including key information processing mechanisms, critical human skills, and a discussion of external factors which act to hamper SA. The implications of each of these issues for the design of systems, including PVI and automation efforts, are discussed. Author

N93-28864# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
OPERATOR AND AUTOMATION CAPABILITY ANALYSIS: PICKING THE RIGHT TEAM
R. M. TAYLOR and S. J. SELCON *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 17 p (SEE N93-28850 11-54) Apr. 1993
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A review of the role of operator and automation capability analysis in aircrew systems design is provided. The changing perceptions of human and machine functionality with increasing machine capability, from early pilot-in-the-loop control, through to the division and sharing of responsibilities for systems management and mission problem solving, are charted. Concepts for the integration of human and machine resources in the performance of physical and cognitive tasks, including decision-making, are discussed in the context of developments in machine intelligence. Operator capability and task analysis, and the modeling of human performance, are seen to have developed from providing tools for system design, to giving critical support for real-time dynamic function allocation in advanced adaptive systems. A model of cooperative teamwork, with the machine conceived of as an electronic-crew teaming resource, is proposed as broad framework for thinking about future adaptive systems requirements. The results of a recent study of human-electronic crew teamwork with RAF Harrier and Tornado aircrew are reported. The results provide evidence for the validity of the teamwork model, and indicate directions for extending the capability for cooperative functioning in future aircrew adaptive systems. Author (revised)

N93-28865# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
COGNITIVE INTERFACE CONSIDERATIONS FOR INTELLIGENT COCKPITS
ROBERT G. EGGLESTON *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 16 p (SEE N93-28850 11-54) Apr. 1993
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The concept of an Intelligent Cockpit as a knowledge-based aiding system is presented. It argues that, in order to maximally support the air crew, user aiding in two areas is required: mission task aiding and interface useability aiding. These areas of aiding are discussed in relation to four different forms of an intelligent cockpit. The central purpose, however, is to introduce the concept of a cognitive design requirement for aiding systems, and to suggest its importance to design solutions expected to achieve crew aiding in both the mission task and interface useability areas. Two arguments are made: (1) A deeper knowledge of human capabilities and limitations is needed to generate effective cognitive design requirements for an aiding system; and (2) more cognitive design requirements are needed for an intelligent cockpit in comparison with a conventional one. Illustrations of possible cognitive design requirements are presented in support of these arguments. Special attention is given to requirements that derive from human capabilities and limitations. Based on the general discussion, it is also concluded that an intelligent cockpit should be a separate module from the traditional systems avionics, since it requires a unique process architecture. Author (revised)

N93-28866# British Aerospace Public Ltd. Co., Kingston-upon-Thames (England). Military Aircraft Div.
ERGONOMIC DEVELOPMENT OF DIGITAL MAP DISPLAYS
ADRIAN MARTEL and GEORGE A. WARD *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 8 p (SEE N93-28850 11-54) Apr. 1993
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In the high workload environment of the cockpit, the importance of efficient transfer of information from visual displays to the pilot is of the highest priority. British Aerospace, Kingston, has developed a prototype Situational Awareness display which successfully combines tactical information with a digital map and aeronautical information. The interface in terms of presentation and functionality is designed to complement the process whereby visual information is cognitively integrated into mental models of Situational Awareness by the user. The development of the display involved a comprehensive literature search on perception and cognition, analysis of map representations, and an iterative evaluation whereby successive prototypes were developed and refined. The many visual design principles which were identified during this work which were successfully incorporated into this display and which may in addition be of great benefit to other displays are detailed. Where displays are being radically revised, a holistic redesign from first principles is preferable to simply adding new features. Author (revised)

N93-28867# Wright Lab., Wright-Patterson AFB, OH.
SYSTEM AUTOMATION AND PILOT-VEHICLE-INTERFACE FOR UNCONSTRAINED LOW-ALTITUDE NIGHT ATTACK
T. O. CHURCH and W. S. BENNETT, II (General Dynamics Corp., Fort Worth, TX.) *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 7 p (SEE N93-28850 11-54) Apr. 1993
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Unconstrained low-altitude night attack is achievable today through automation and integration of current technologies. Many of these technologies are advanced avionic systems that still require additional development before they are production-ready. However, their performance and synergistic benefits have been demonstrated. Additional efforts are still warranted to increase system safety, improve situational awareness, decrease pilot workload, and provide a more effective weapon system. Author

N93-28870# Rockwell International Corp., Los Angeles, CA.
REQUIREMENTS FOR PILOT ASSISTANCE IN A THRUST-VECTORING COMBAT AIRCRAFT
EMILY HOWARD and ROBERT E. BITTEN *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 15 p (SEE N93-28850 11-54) Apr. 1993
(Contract(s)/Grant(s): N00019-88-C-0288)
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With the emergence of thrust-vectoring aircraft such as the X-31 and F-22, new questions arise regarding the maximum potential of this technology for increasing air-to-air combat effectiveness. Recent dome-to-dome (man-in-the-loop) simulations have demonstrated a significant increase in close-in air combat effectiveness with the addition of thrust vector capability. Much of this increased effectiveness can be attributed to the ability of the thrust-vectoring aircraft to continue maneuvering while operating well beyond conventional aircraft stall limits. Such poststall maneuvering (PST) can dramatically increase an aircraft's turn rate while simultaneously minimizing its turn radius, providing a significant tactical advantage in close in air combat. Comparisons with all-digital (computer-in- the-loop) simulations under the same test conditions, however, show that the combat effectiveness of PST is consistently greater within the all-digital analyses than within the all-manned analyses. These comparisons are summarized and whether pilots may require supplemental assistance in order to exploit the full potential of PST utility is considered. Through analysis of both man- and computer-in-the-loop combat simulations, requirements for pilot assistance were tentatively identified, along with some of the methods applicable to meeting these requirements. These methods include expanded training, improved displays, and increased automation. The results of this analysis, based upon the studies available to date, are presented. Plans for further analysis and validation studies are described.
Author (revised)

N93-28872# National Aerospace Lab., Amsterdam (Netherlands).
OVERVIEW OF COCKPIT TECHNOLOGY RESEARCH AND DEVELOPMENT PROGRAMS FOR IMPROVEMENT OF THE MAN/MACHINE INTERFACE: REVIEW OF THE AGARD AVP SYMPOSIUM HELD IN MADRID, MAY 1992
P. J. M. URLINGS and E. W. PIJPERS *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 12 p (SEE N93-28850 11-54) Apr. 1993
(AGARD-CP-520) Copyright Avail: CASI HC A03/MF A03

A review of the AGARD Avionics Panel (AVP) symposium on 'Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface', held in May 1992 at Madrid is provided. The theme of this symposium was limited to the 'machine-side' since a subsequent AGARD symposium at Edinburgh, Scotland, later that year was scheduled to cover the 'man-side' of the subject. The main findings of the Madrid symposium were summarized for presentation in Edinburgh. The complete text of the papers of the AVP symposium can be found in AGARD Conference Proceedings CP-521. Author (revised)

N93-32240# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
NUTRITION, METABOLIC DISORDERS AND LIFESTYLE OF AIRCREW [LES DESORDRES METABOLIQUES DUS A LA DIETETIQUE ET HYGIENE DE VIE DES EQUIPAGES D'AERONEFS]
Mar. 1993 230 p Symposium held in Oslo, Norway, 19-23 Oct. 1992
(AGARD-CP-533; ISBN-92-835-0703-7; AD-A267031) Copyright Avail: CASI HC A11/MF A03

These proceedings include the Technical Evaluation Report and 30 papers of the symposium sponsored by the AGARD Aerospace Medical Panel and held in Oslo, Norway from 19-23 Oct. 1992. The theme of the symposium was to review and update the knowledge pertaining to diet and nutrition as it applies to aircrew. The metabolic disorders, including hyperlipidemia and alterations of carbohydrate metabolism, are common problems in aviation medicine that demand specific attention and management by NATO flight surgeons. Hyperlipidemia is a cardiovascular risk

factor that by itself or when combined with cigarette smoking and sedentary behavior as well as other risk factors presents a formidable problem for all NATO Air Forces as this directly impacts at pilot performance. Performance may also be affected by inadequate crew rest, environmental extremes and time zone shifts, all of which were illustrated in the Persian Gulf Conflict. For individual titles, see N93-32241 through N93-32269.

N93-32241# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Delft (Netherlands). Dept. of Human Nutrition.

AN AUTOMATED PROCESSING SYSTEM FOR FOOD FREQUENCY AND NUTRITION KNOWLEDGE QUESTIONNAIRE

A VANERP-BAART, M. J., I. C. KISTEMAKER, and M. R. H. LOEWIK *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 3 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A01/MF A03

In surveys and intervention studies, food frequency questionnaires are often used to assess habitual dietary intake. Although this is a relatively quick and simple method, the number of subjects to be examined can still be enormous. So, without a good system, the time needed for the processing of the amount of data may be prohibitive for starting such a project. To structure and speed up this work, FOFRIPS, a food frequency interactive processing system was developed. The starting point was that not each developed specific questionnaire should be automated, but instead only the general procedures of the data processing. Author (revised)

N93-32242# University of South Florida, Tampa, FL. Coll. of Public Health.

NUTRITIONAL ASSESSMENT OF UNITED STATES TACTICAL AIR COMMAND PILOTS

S. D. HART YEVICH, S. J. YEVICH, and C. MORRISON *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 5 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A01/MF A03

The nutritional status of 184 TAC fighter pilots was analyzed for caloric intake, macronutrient composition, alcohol intake, and meal frequency. The dietary habits of fighter pilots relative to their age, family configuration, and level of exercise were also examined. The diets of a sub-group of 43 F-16 student fighter pilots were correlated with the subjective graded performance of a Basic Fighter Maneuver. Pilots energy consumption of 2800 kcal fell within the suggested range for the average U.S. male. The macronutrient composition of their diets was better than that of the mean U.S. male, comprising an average of 46% carbohydrates, 34% fats, 15% protein, and 5% alcohol. Missed meals on the day of flying were a frequent occurrence. The older age pilots consumed less fat than their younger counterparts, but their intake of alcohol was greater. Family configuration had no effect on alcohol consumption, caloric intake, or dietary behavior. Pilots who exercised 4 to 7 day a week were heavier than the non-exercisers, and the non-exercisers consumed more alcohol. No statistical difference could be found between total performance scores in the sub-group of F-16 student pilots and any deficiency or excess of specific dietary components or any combinations of these components. Alcohol consumption was shown to be associated with a low G-tolerance score. Author

N93-32243# Oslo Univ. (Norway). Inst. for Nutrition Research.

PORTABLE EQUIPMENT DEVELOPED TO ESTIMATE ENERGY EXPENDITURE BY SIMULTANEOUS RECORDING OF HEART RATE AND BODY POSITION

A. LOVO, B. E. HUSTVEDT, A. CHRISTOPHERSEN, C. C. CHRISTENSEN (Royal Norwegian Air Force, Oslo.), and H. T. ANDERSEN (Royal Norwegian Air Force, Oslo.) *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 5 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A01/MF A03

The operating principle of Actireg, a new device for registration of changes in human body positions, is described. It is robust and functions well also during prolonged periods of high physical activity, in contrast to accelerometers and other devices used as motion sensors. Preliminary experiments indicate that combined use of heart rate and body position recording for estimation of energy expenditure may be superior to the use of heart rate registrations alone. However, validation experiments with doubly labeled water or a whole body calorimeter are needed in order to reach a firm conclusion on this point. Author

N93-32244# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Bretigny sur Orge (France). Div. de Physiologie Metabolique et Hormonale.

PROTEIN REQUIREMENTS IN HYPOXIA OR HYPOKINESIA

C. Y. GUEZENNEC, A. X. BIGARD, and D. TAILLANDIER *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 5 p (SEE N93-32240 12-54) Mar. 1993
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Muscle trophicity is under the influence of four major factors which are nutrition, nervous stimulation, muscle activity, and hormones. Numerous works have shown that substrate availability acts directly on muscle protein synthesis. The glucidic and proteic substrates regulate in a coordinated way the muscle proteosynthesis so that the attention was focused on the role of protein nutriment to protect muscle against protein wasting. Several conditions could decrease protein body stores among which are hypoxia exposure or hypokinesia. Both environmental factors are results of aerospace or military events. Two studies were conducted in order to evaluate the role of protein diet on protein metabolism during hypokinesia or hypoxia exposure. Author

N93-32245# Air Force Systems Command, Brooks AFB, TX. Armstrong Lab.

NUTRITION FOR A TYPICAL MAC CREW DURING DESERT STORM

J. FRENCH and T. J. COOK *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 6 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

Data on inflight meals were collected during a 30-day field experiment conducted by the Armstrong Laboratory designed to evaluate fatigue in C-141 Military Airlift Command (MAC) aircrew. Flight meal information was collected for one five-member crew throughout the area of operation during the last week of Desert Storm and for 3 additional weeks. Focus is on the nutritional components of a representative sample of the inflight meals provided to MAC aircrew. Nutritional analysis was based on fifteen in flight meals obtained from various Desert Storm staging bases. Analysis concerned kilocalories, protein, carbohydrate, fat, cholesterol, sodium, and saturated fats present in the average meal. The mean value for these components, constituting an average inflight meal, were 1758 Kcal, 53 g protein, 233 g carbohydrate, 66 g fat, 136 mg cholesterol, 3240 mg sodium and 20 g saturated fats. The limitations of this opportunistic evaluation and the need for additional field analyses of inflight meals and aircrew diets is discussed. Author

N93-32246# Institute of Aviation Medicine, Oslo (Norway).

CHANGES IN FOOD AND ENERGY INTAKE IN MILITARY AIRCREW

C. HELLE, K. KVAMSOE, K. TRYGG, and H. T. ANDERSEN *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 7 p (SEE N93-32240 12-54) Mar. 1993
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Military flying is a demanding profession requiring excellent performance during operations. Because the modern western society includes several undesirable lifestyle patterns, dietary counseling has been given increased attention over the past few years in Norway where the government has arrived at an official policy of nutritional standards. In order to provide information about the nutritional pattern of military aircrew, the Institute of Aviation Medicine (IAM) carried out a food survey on aircrew at Andoya Air Base in 1986. The present survey is a follow-up study of the 1986 study, using the same squadron and the same method as the previous study. Our survey has three aims. The first one is to detect any change in aircrew diet over the last six years. Secondly, since the 1986 survey showed that the aircrew took a nutritionally better diet than the average Norwegian population, it was investigated whether this group is still ahead. Finally, to what extent the irregular working and resting conditions of aircrew influence their meal schedule was studied. Author (revised)

N93-32247# Spanish Air Force, Talavera AFB (Spain).
TRIAL OF EMERGENCY RATION OF THE SPANISH AIR FORCE
ANTONIO MENDEZ MARTIN and JOSE IGNACIO PERALBA VANO *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 8 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

The response of normal young volunteers to the Spanish Air Force (SAF) Emergency Rations (ER) (NATO code 8.970-33G02-0140) as the only nutriment during seven consecutive days was tested. The nutritional and metabolic response plus the psychological acceptability of the ER was evaluated. All the volunteers were medical students who were fully informed about the trial and its conditions. Each proband received a daily diet with only ER (1.000 Kcal/day, 10 chewable bars/210 grms total weight) equivalent to 580 Kcal/sqmeter/body surface/day with two optional flavors, orange or chocolate. Quantity of liquids per day/probands was from 1.5 to 2.0 liters. Probands carry out their normal daily activity without changes in usual timing except meals. The trial duration was 7 days. The conclusion was that the SAF ER provides satisfactory nutrition for short periods of time without impairing the daily activities or altering the metabolic and nutritional parameters in a normal young population. Author (revised)

N93-32248# Italian Air Force Pratica di Mare, Rome.
IDIOPATHIC REACTIVE HYPOGLYCEMIA IN A POPULATION OF HEALTHY TRAINEES OF AN ITALIAN AIR FORCE MILITARY SCHOOL
STEFANO FARRACE, LUCA URBANI, LORENZO SAKARA, and CLAUDIO DEANGELIS *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 3 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A01/MF A03

Idiopathic Reactive Hypoglycemia (IRH) was investigated among a population of young trainees of an Italian Air Force military school. One hundred and twenty male healthy subjects underwent a 300 min Oral Glucose Tolerance Test (OGTT) after an overnight fasting. Nine out of 120 subjects (group A: 7.5 percent) showed a glycemia nadir below 50 mg/dl. Moreover, in group A eight out of nine subjects reported symptoms referable to clinical hypoglycemia during the glycemia nadir. Furthermore, a lack in glucagon response to hypoglycemia was observed in group A. Data are suggestive for the presence of Idiopathic Reactive Hypoglycemia in group A subjects. Data suggest that IRH may be considered relevant as a possible reason of in-flight accident due to human factor. Author (revised)

N93-32255# Portuguese Air Force, Alfragide (Portugal). Centro de Medicina Aeronautica.
NUTRITIONAL AND LIFESTYLE STATUS OF 50 PILOTS OF THE PORTUGESE AIR FORCE
F. B. OLIVEIRA, N. L. RIBEIRO, and S. R. SILVEIRA *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 2 p (SEE N93-32240 12-54) Mar. 1993
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A group of 50 pilots selected from a non-academic pilot background, born between 1947-1960, had their body weight, smoking and drinking habits, and blood pressure evaluated during a 10 year survey. Fifty six percent had Real Body Weight (RBW) greater than the Ideal Body Weight (IBW), with a 28 percent of RBW greater than + 10Kg of the IBW. Smoking habits were over 20 cigarettes per day in 36 percent and only 10 percent didn't smoke. Declared alcoholic intake, over average consumption, was admitted in 14 percent, with 3 alcoholic psychiatric treatment and 1 admission to hospital with Acute Alc. Hepatities. Blood pressure was over normal range in 12 percent. A modified clinical and Laboratorial screening is being applied, since 1991. Author (revised)

N93-32256# Hellenic Air Force General Hospital, Athens (Greece).
CORRELATION OF LIFE-STYLE AND DIETARY CONCOMITANTS OF GREEK PILOTS WITH SERUM ANALYTES
C. DASKALOPOULOS, J. PALERMOS, T. ZOGA, A. STAVROPOULOS, and K. KYRIAKOS *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 4 p (SEE N93-32240 12-54) Mar. 1993
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Certain serum analytes (glucose, total cholesterol, HDL cholesterol, triglycerides, uric acid, and y-glutamyltransferase) were correlated with some lifestyle variables (dietary features, anthropometrics, and physical exercise) in military (n=157) and civilian (n=157) male pilots in order to determine a possible relationship between these variables and their health status. The subjects, randomly selected within a certain period, were currently active without any history of coronary heart disease or diabetes mellitus and were not receiving any medication. In total, military pilots had statistically significant increased mean values of glucose, while a correlation of the mean values between groups with similar age showed that military pilots had increased cholesterol values and civilian pilots had increased triglycerides, LDL cholesterol, and y-GT values. Both had an average body mass index (weight/height(sup 2)) of 25 and very few of them were following an effective physical exercise program toward lowering cholesterol level. They preferred taking few (82.1 percent, 80.9 percent for military and civilian pilots respectively) but large meals (59.2 percent, 52.2 percent respectively). Concerning food composition, almost 30 percent of them were eating meals containing 38 percent or more fat, and 15 percent of them were eating meals with less than 44 percent carbohydrates of total daily caloric intake. Finally, our data suggest that: (1) the concentration of certain blood analytes (glucose, cholesterol) should be reduced, (2) an effective regular aerobic exercise program should be followed, and (3) meals should be altered toward the pattern of 'many and small' per day containing less fat and more carbohydrates. Author (revised)

N93-32257# Air Force Systems Command, Brooks AFB, TX. Armstrong Lab.
THE LIFESTYLE AND DIETARY CONSUMPTION PATTERNS OF UNITED STATES AIR FORCE AVIATORS WITHIN AIR TRAINING COMMAND AT RANDOLPH AIR FORCE BASE, TEXAS
TAMMY J. COOK, JONATHAN FRENCH, and BETH SENNE-DUFF (Incarnate Word Coll., San Antonio, TX.) *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 8 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

A lifestyle survey was developed and distributed to two flying squadrons and to the rated officers of the 12th Flying Training Wing to examine lifestyle habits and dietary consumption patterns. Blood lipid profiles were gathered and classified using National Cholesterol Education Program (NCEP) guidelines. Eighty two of 100 surveys were returned, and 75 completed 24-hour dietary recalls. As a group, these surveyed aviators consumed significantly less total fat, saturated fat, and dietary cholesterol than found in the typical American diet. Ninety three percent were non-smokers and 16 percent did not drink alcohol. Twenty eight percent described themselves as overweight by 6-10 pounds. Sixty-two percent exercised aerobically with 56 percent exercising three times a week or more. Monitoring total blood cholesterol level was important to 86 percent of respondents. Using NCEP guidelines, 36 percent of randomly sampled aviators were identified with LDL cholesterol which may warrant dietary or lifestyle intervention. Future research efforts and a proposed approach for educational intervention are discussed for this population. Author (revised)

N93-32258# Spanish Air Force, Talavera AFB (Spain).
OBJECTIVE IMPROVEMENTS OBTAINED BY CONTROL OF DIET AND PHYSICAL TRAINING IN SPANISH AIR FORCE FIGHTER PILOTS
JOSE L. GARCIA ALCON, MA DEL ROSARIO DURAN TEJEDA (Extremadura Univ., Badajoz, Spain.), and JUAN M. MORENO VAZQUEZ (Extremadura Univ., Badajoz, Spain.) *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 7 p (SEE N93-32240 12-54) Mar. 1993
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The effect of diet and sport practice in a homogeneous--age, sex and environmental stress--group of pilots (n=90) was investigated in order to evaluate the impact of diet and sport practice on body weight and plasma lipid levels. The dietary intake was a typical mediterranean diet (55-60 percent carbohydrates, 25 percent lipids, and 15-20 proteins and 3000 Kcal daily). It was controlled by the Flight Surgeon Office. The sport practice was grounded in a physical training program for pilots, directed by the Physical Training Officer. A marked difference in all studied lipid parameters was found between groups with free diet versus controlled diet. A difference in HDL-C levels and TC/HDL-C ratio was found between groups with regular physical training versus free sport practice. Author (revised)

N93-32259# Air Force Systems Command, Brooks AFB, TX. Armstrong Lab.
THE INFLUENCE OF DIETARY COUNSELING AND CARDIAC CATHETERIZATION ON LIPID PROFILES IN AMERICAN MILITARY AVIATORS
B. TUOMALA, R. MUNSON, W. BESICH, and P. CELIO *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 6 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

The purpose was to determine the combined effect of dietary counseling and cardiac catheterization on lipid profiles when compared to a control group that did not receive dietary counseling or cardiac catheterization. The medical records and lipid profiles of 109 military aviators who underwent cardiac catheterization and dietary counseling and 109 matched controls who received neither were reviewed. All individuals were seen twice at the Aeromedical Consultation Service (ACS) between July 1987 and March 1992. Lipid profiles of the two groups were compared during their first evaluation and again at follow-up. Overall, there was a trend towards improvement in lipid profiles, but the changes between the 2 groups were not statistically significant. The cardiac catheterization group was divided into 3 subgroups based on severity of disease and compared to their matched control. The subgroup with minimal coronary artery disease (max lesion is less than 30 percent) showed a small but statistically significant improvement in HDL cholesterol. Otherwise the aviators knowledge of his angiographic results did not lead to any significant change in lipid profiles. This suggests that lipid profiles in aviators is not significantly affected by the combined influence of nutritional counseling and cardiac catheterization. The design of this study did not preclude members of either group from receiving dietary recommendations from physicians as part of their overall evaluation. Author (revised)

N93-32260# Belgian Air Force, Brussels (Belgium).
BIOLOGICAL PARAMETERS AND CARDIOVASCULAR RISK FACTORS WITH THE FLYING PERSONNEL OF THE BELGIAN ARMED FORCES
J.-P. VASTESAEGER and P. VANDENBOSCH *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 3 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A01/MF A03

Research was done into biological parameters and cardiovascular risk factors of all pilots and navigators of the Belgian Armed Forces (Air Force and Light Aviation) of more than 45 years old and was evaluated according to age categories. The evolution of these data was analyzed with a retrograde study. Special attention was paid to the differences between Light Aviation and Air Force and between the respective linguistic groups. Author (revised)

N93-32261# Royal Norwegian Air Force, Oslo (Norway).
CHANGES IN SOME LIFESTYLE PARAMETRES IN NORWEGIAN PILOTS AS STUDENTS, AND AFTER 6 AND 12 YEARS OF SERVICE
I. L. NESLEIN, C. C. CHRISTENSEN, L. LIAN, T. RODE, and H. T. ANDERSEN *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 3 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A01/MF A03

Medical records from candidates accepted for military training in the Royal Norwegian Airforce (RNoAF) between 1978 to 1980, and who still are on flying standards in the RNoAF, were examined. Cholesterol, HDL-cholesterol, resting heart rate, blood pressure, body weight, and maximum oxygen uptake were studied over a 12 year period, i.e. at approximately 20, 26, and 32 years of age. Our pilots gain weight at a rate twice that of the general Norwegian population. They maintain the same physical fitness from the age of 20 to 26, and from 26 to 32 there is a significant increase in maximum oxygen uptake. A 32 year old pilot is in a distinctly better physical condition, both compared to his younger colleagues, and to the average Norwegian of the same age. There is also a significant increase in serum-cholesterol from the age of 20 to 32. HDL-cholesterol and resting heart rate remained unchanged over the period. Systolic blood pressure was unchanged from 20 to 26, but decreased significantly from 26 to 32. Diastolic blood pressure dropped significantly from 20 to 26 years of age. Dietary/lifestyle consultation, as a matter of routine, may be of great importance to young pilots in order to prevent coronary heart diseases in the future. Such information should be given at an early stage, before symptoms occur. Author (revised)

N93-32262# Centro de Instruccion de Medicina Aeroespatial, Madrid (Spain).
SURVEY OF SMOKING HABITS IN THE SPANISH AIR FORCE
F. RIOS TEJADA, C. ALONSO RODRIGUEZ, J. J. CANTON ROMERO, and J. A. AZOFRA GARCIA *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 7 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

Cigarette smoking is a well known cause of major illnesses in the general population, illnesses that can impair a pilot's performance of duty and even result in temporary or permanent disqualification of the aircrew member. This results in a diminished return on a significant investment of time and resources used to train the individual, a loss that is even more critical as the competition for such resources in an era of budget reduction, becomes more intense. The purpose is to review the diseases and physiologic changes related to cigarette smoking, especially as they relate to the flying environment. Then the prevalence of both the smoking habit and these related impairments in the Spanish Air Force aircrews are specifically examined. Finally, this data is utilized, compared to previous epidemiologic surveys in this target population, to draw conclusions regarding the effectiveness of past efforts at reducing cigarette smoking and propose future methods that might be used to reduce the negative impact of smoking related illness on the SAF mission.
Author (revised)

N93-32263# Army Natick Research and Development Command, MA.
THE EFFECTS OF AN ANTIJET LAG DIET
CHARLES A SALTER, LAURIE S. LESTER, EDWARD HIRSCH, MARGARET MOLINE (Cornell Univ., White Plains, NY.), CHARLES P. POLLAK (Cornell Univ., White Plains, NY.), and DANIEL R. WAGNER (Cornell Univ., White Plains, NY.) *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 13 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A03/MF A03

The unpleasant symptoms surrounding jet lag or phase shifts (fatigue, insomnia, etc.) generally interfere with biological rhythms, performance, and subjective well being. A popular 'jet lag diet' has been touted widely as an effective countermeasure to alleviate symptoms through systematic alternation of high (greater than 3600 calories per day) and low (less than 800 calories per day) food intake, timed consumption of methyl xanthines, high protein breakfasts and lunches, and high carbohydrate dinners. Unfortunately, this system as a whole has never been adequately tested with humans. Fifteen male subjects (aged 18-25) lived individually in time-isolation apartments for 15 consecutive days.

For the first seven days they ate and slept according to their usual schedule. During the seventh night, they were phase advanced 6 hours, to simulate an easterly jet flight, and maintained their new schedules for 8 days. The eight control subjects consumed their normal diet throughout the study, while the seven diet group subjects consumed the 'jet lag diet' prescribed by Charles Ehret. All subjects experienced jet lag as evidenced by disrupted sleep and body temperature rhythms, mood and performance decrements, and lessened physical activity. The antijet lag diet did not lessen the severity of these symptoms and, in fact, worsened sleep. Although, the two groups did not differ with respect to sleep latency, duration, or composition before the simulated jet lag, afterwards subjects in the diet group slept on average 30 minutes less and were 31 percent less efficient than the control subjects. These results indicate that a popular antijet lag diet is not effective in young male subjects and may even worsen symptoms for air crew members relying upon it.
Author (revised)

N93-32264# Air Force Systems Command, Brooks AFB, TX. Armstrong Lab.

SUBJECTIVE MOOD AND FATIGUE OF C-141 CREW DURING DESERT STORM

JONATHAN FRENCH, PATRICIA A. BOLL, ROGER U. BISSON, KELLY J. NEVILLE, WILLIAM F. STORM, STEPHEN H. ARMSTRONG, TIMOTHY SLATER, and ROBERT L. MCDANIEL (Military Airlift Wing, 437th, Charleston AFB, SC.) *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 6 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

Profile of Mood States (POMS) data were used to assess the subjective condition of C-141B air crew members during Operation Desert Storm (March/April, 1992). The POMS dimensions used were anger, fatigue, vigor, tension, depression, and confusion. Data were collected during 2 intervals of the MAC crew duty day; legal for alert (LFA) and crew rest (CR) intervals. The POMS dimensions correlated with one another during the 30-day study. Fatigue, vigor, and confusion were different between LFA and CR suggesting that the CR interval was restorative. During both LFA and CR intervals, cumulative flight hour blocks from 0-75, 76-100, 101-125, and 126-150 hours per month revealed no significant effects on subjective mood states. However, mood was sensitive to conditions of recent (1-2 days) flight hours and sleep hours in combination with cumulative flight hours per 30-days. In particular, when cumulative flight hours exceeded 125 hours per 30-day period, the vigor dimension was affected by the amount of sleep and flight hours in the most recent 24-48 period. Therefore, attending to recent sleep and flight hours as well as cumulative flight hours per 30-day interval may reduce fatigue and improve mood when operational pressures require exceeding the normal 125 flight hours per 30-days.
Author (revised)

N93-32265# Air Force Systems Command, Brooks AFB, TX. Armstrong Lab.

C-141 AIRCREW SLEEP AND FATIGUE DURING THE PERSIAN GULF CONFLICT

PATRICIA A BOLL, WILLIAM F. STORM, JONATHAN FRENCH, ROGER U. BISSON, STEPHEN D. ARMSTRONG, TIMOTHY SLATER, WILLIAM E. ERCOLINE (Krug Life Sciences, Inc., San Antonio, TX.), and ROBERT L. MCDANIEL (Military Airlift Wing, 437th, Charleston AFB, SC.) *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 13 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A03/MF A03

Subjective fatigue ratings and sleep logs were collected from pilots flying C-141 strategic airlift missions during Operations Desert Shield and Desert Storm. Descriptive summaries of the data are presented for duty-day, crew rest away from home base, and crew rest at home base. The implications of selected findings are presented as recommendations on management of aircrew work/rest schedules during sustained airlift operations. Author

N93-32266# Army Aeromedical Research Lab., Fort Rucker, AL.

THE EFFECTS OF COCKPIT HEAT ON AVIATOR SLEEP PARAMETERS

J. LYNN CALDWELL, ROBERT THORNTON, JACQUELYN Y. PEARSON, and BARBARA L. BRADLEY *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 10 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

Aviators are frequently required to work in hot environments while performing the complex cognitive tasks necessary to fly their aircraft. Objective measures of sleep were taken to determine the effects of exposure to high cockpit temperatures. Army helicopter pilots were required to fly a UH-60 simulator while wearing NBC IPE in temperatures of 35 C and 41 C. Additionally, various cooling vests were tested to determine if these cooling mechanisms would alleviate any heating effect seen in sleep parameters. During the day, pilots flew the simulator continuously for 6 h unless they were withdrawn because of excessive core temperature or they voluntarily withdrew. During the night, pilots slept in a cool bedroom in the laboratory while their sleep patterns were recorded by electroencephalography. Analyses of the data indicated when core body temperature rose during the flight by at least 1 C and the flight was at least 5 h in length, rapid eye movement (REM) sleep was significantly reduced. No rise in slow wave sleep (SWS) was seen although there was a tendency for the relationship between SWS and REM sleep to be altered. The results suggest aviators operating in a hot environment for a long period of time may have altered sleep the following night. Author (revised)

N93-32267# Centre National de la Recherche Scientifique, Paris (France).

HUMAN FACTORS AND THE SAFETY OF FLIGHTS: THE IMPORTANCE OF THE MANAGEMENT OF SLEEP [FACTEURS HUMAINS ET SECURITE DES VOLS: IMPORTANCE DE LA GESTION DU SOMMEIL]

P. CABON, R. MOLLARD, A. COBLENTZ (Paris V Univ., France.), J. P. FOUILLOT (Paris V Univ., France.), and J. J. SPEYER (Airbus Industrie, Toulouse, France.) *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 11 p (SEE N93-32240 12-54) Mar. 1993 In FRENCH
(AGARD-CP-533) Copyright Avail: CASI HC A03/MF A03

In the field of civil air transport, the fatigue and sleep of the pilots becomes more and more of a concern in the area of flight safety, in particular for long distance flights. Indeed, these flights produce important stresses for the pilots: fast and multiple time shifts, work at night or with shifted schedules with occasionally very high amounts of work. The cumulated effect of these stresses involves disturbances of the circadian rhythms and sleep deprivations reducing the performance and the alertness level of the pilots. These difficulties are particularly elevated by the lengthening of the duration of flights with the modern planes such as the Boeing 747-400 and Airbus A340 (flights can attain a duration of 14 hours). These flights which remain for the moment limited to certain types of routes will tend to become more common in the near future. They are carried out with a reinforced crew, the French regulation of civil aviation prohibiting the work of pilots beyond one period of 8 or 10 hours according to the type of aircraft. The relatively recent appearance of these aircraft raises the very delicate question of the management of sleep for the whole crew, during the stopover and the flight. To these physiological constraints, it is necessary to add the modifications of the activity of piloting on the modern aircraft. Sometimes the increasing automation of the cockpits contributes to making the tasks of the pilot very monotonous as well as reducing the sensory stresses considerably. Similar work was also carried out in the military field. The cumulated action of these two factors, sleep disturbances and monotony of activity, are likely to involve states of hypovigilance which can appear, in certain circumstances, prejudicial to the safety of the flight. The results of research aimed at the study of the duration and quality of sleep of the crews of civil aircraft during rotations including long distance flights of durations equal to or greater than 8 hours. Transl. by FLS

N93-32268# Air Force Systems Command, Brooks AFB, TX. Armstrong Lab.

DIGITAL FLIGHT DATA AS A MEASURE OF PILOT PERFORMANCE ASSOCIATED WITH FATIGUE FROM CONTINUOUS OPERATIONS DURING THE PERSIAN GULF CONFLICT

ROGER U. BISSON, KELLY J. NEVILLE, PATRICIA A. BOLL, JONATHAN FRENCH, WILLIAM R. ERCOLINE (Krug Life Sciences, Inc., San Antonio, TX.), ROBERT L. MCDANIEL (Military Airlift Wing, 437th, Charleston AFB, SC.), and WILLIAM F. STORM *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 11 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A03/MF A03

The results of a field study using the C-141 Digital Flight Data Recorder (DFDR) to evaluate whether fatigue affected piloting precision during the Persian Gulf conflict are described. This is the first time digital flight data from the C-141 was used to evaluate routine aircrew performance. Five C-141 military transport crew were granted scheduling priority to quickly accumulate 150 flight hours in less than 30 days. Fatigue estimates were based upon activity logs, fatigue ratings, oral temperature, and mood surveys. Eighty seconds of the instrument landing system (ILS) final approach above decision height were isolated from digital flight data downloaded after each flight. Both an average and a standard deviation were calcualted for airspeed, heading, vertical velocity, pitch, and roll for each of the 80 second ILS segments. The standard deviations served as estimates of piloting precision and were correlated to fatigue measures. No significant differences in piloting precision categorically attributable to fatigue were found. However, individual examples of decreased precision associated with high fatigue levels were observed. These deviations did not occur with enough regularity to conclude whether fatigue or other factors were the root cause. DFDR data can be a sensitive measure of performance, but the operational setting of Desert Storm did not permit control of important variables in this first time effort. The findings suggest that DFDR assessment of flying precision could be of value in controlled studies of fatigue, workload, or drugs that affect pilot performance. Future studies need to evaluate digital flight data versus other cognitive and psychomotor tasks that are sensitive to changes in performance. Transl. by FLS

N93-32269# Army Natick Research and Development Command, MA. Military Performance and Neuroscience Div.

EFFECTS OF CAFFEINE ON MENTAL PERFORMANCE AND MOOD: IMPLICATIONS FOR AIRCREW MEMBERS

HARRIS R. LIEBERMAN, BERNARD J. FINE, JOHN L. KOBRICK, and JOHN D. E. GABRIELI (Stanford Univ., CA.) *In* AGARD, Nutrition, Metabolic Disorders and Lifestyle of Aircrew 10 p (SEE N93-32240 12-54) Mar. 1993
(AGARD-CP-533) Copyright Avail: CASI HC A02/MF A03

Caffeine is generally regarded as the most widely used drug in the world. However, it is also a food constituent. Its acute effects on behavior appear to be greater than those of any other food constituent as they are detectable when caffeine is administered in doses found in single servings of coffee, tea, and soft drinks. Caffeine affects the central nervous system by binding to adenosine receptors, and it has acute and chronic, dose dependent effects on brain function. Low and moderate doses have beneficial effects on mental performance but high doses may have adverse effects. Tolerance develops to continued use of caffeine, so that its acute effects are altered when it is used chronically in high doses. Physical and mental symptoms associated with sudden withdrawal of caffeine have also been reported. The acute effects of caffeine on vigilance, simple and complex cognitive performance, and mood state are discussed. Doses equal to single servings of beverages consistently improve auditory and visual vigilance. In addition, moderate doses of caffeine increase self-reported alertness. The duration and magnitude of these effects on individuals are related to habitual caffeine consumption and interact with tobacco use. In view of its dose-related beneficial and deleterious effects, aircrew personnel, flight surgeons, military commanders, and planners should have knowledge of the potential influence of caffeine on performance, especially vigilance, and mood, as well as the consequences of its abrupt withdrawal. Author (revised)

N94-23976# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

VISUAL PROBLEMS IN NIGHT OPERATIONS [PROBLEMES DE VISION DANS LES OPERATIONS DE NUIT]

May 1992 96 p In ENGLISH and FRENCH Lecture series held in Madrid, Spain, 1-2 Jun. 1992, in Soesterberg, Netherlands, 4-5 Jun. 1992, and in Brooks AFB, TX, 15-16 Jun. 1992
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The aim of this Lecture Series is to provide the aeromedical specialist with a thorough understanding of the physiology of the visual system with particular concentration on the impact of the environment presented during night tactical air operations. Methods to preserve, protect, or enhance unaided night vision will be discussed. Information concerning visual performances with electro-optic devices derived from aeromedical research and field experiences will be detailed to provide the medical specialists, the engineers, and operational pilots with appropriate understanding of these increasingly common operational tools. This Lecture Series, sponsored by the Aerospace Medical Panel of AGARD, was implemented by the Consultant and Exchange Programme of AGARD. For individual titles, see N94-23977 through N94-23984.

N94-23977# Aerospace Medical Research Labs., Williams AFB, AZ. Aircrew Training Research Div.

NIGHT OPERATIONS

WILLIAM E. BERKLEY *In* AGARD, Visual Problems in Night Operations 4 p (SEE N94-23976 06-54) May 1992
(AGARD-LS-187) Copyright Avail: CASI HC A01/MF A01

Strategists have long sought to exploit the night in military operations, not only to avoid detection and as a means to defeat visually or optically aimed weapons, but also to deny the enemy an opportunity to rest or resupply his troops. With the advent of practical and effective imaging devices, true night war fighting capability has at last become a reality (as demonstrated in the recent Gulf War). It is safe to assume that night military operations will receive even more emphasis in the future. Current aviation activities range from basic single pilot helicopter operations with night vision goggles (NVG's) to complex missions utilizing a mix of highly sophisticated aircraft with multiple sensors, precise navigational capabilities, and advanced weapons delivery systems. Author (revised)

N94-23978# Centre d'Enseignement et de Recherches de Medecine Aeronautique, Paris (France). Dept. Ergonomie Aerospatiale.

PHYSICAL ASPECTS OF THE VISUAL STIMULUS [ASPECTS PHYSIQUES DU STIMULUS VISUEL]

JEAN-PIERRE MENU *In* AGARD, Visual Problems in Night Operations 8 p (SEE N94-23976 06-54) May 1992 In FRENCH
(AGARD-LS-187) Copyright Avail: CASI HC A02/MF A01

The various physical and psychophysical aspects of the visual stimulus are considered. It is a question of defining as precisely as possible the physical stimulation of input to the visual systems (nature of radiation, light intensities, colors, and organization in space and time). It is often difficult to dissociate the physical aspect from the psychophysical aspect. This last aspect translates the impact of the physical aspect on the socket and the treatment of information through the visual channel. It is consequently important to define as precisely as possible the operation of the retinal sensor. Mechanisms of the integration of information are described. The physical structure of the images of several systems of substitution to night vision are analyzed. Transl. by FLS

N94-23981# Centre d'Enseignement et de Recherches de Medecine Aeronautique, Paris (France). Dept. Ergonomie Aerospatiale.

MULTI-SENSORAL APPROACH TO NIGHT FLIGHT: PERCEPTIVE AND COGNITIVE LIMITATIONS [APPROCHE MULTI-SENSEURS POUR LE VOL DE NUIT: LIMITATIONS PERCEPTIVES ET COGNITIVES]

RENE AMALBERTI *In* AGARD, Visual Problems in Night Operations 9 p (SEE N94-23976 06-54) May 1992 In FRENCH
(AGARD-LS-187) Copyright Avail: CASI HC A02/MF A01

Night-flight activities have significantly grown to allow Forces being permanently operational. The level of performance for these activities is expected to be the same as it is in day time. Thus,

visual support systems have been designed to mitigate the consequences of night-vision limitations, e.g. Electro-optical systems (radar), NVG, FLIR, and Real-time terrain image. Some of these support-systems are mixed, using several sources although they provide the pilot with only one resulting integrated image. Moreover, when the pilot continues to have a direct vision of the external world (vision through the optical system), the human vision has to be considered as another point of view to be integrated with this type of visual support system. This is typically what is termed the integrated multi-sensor and sensory approach. Humans have a special position in such conditions: first, from a perceptive point of view, although they are impaired by night-conditions, their eyes complement machine vision. Second, from a reasoning and decision making point of view, they must adapt their mental processes to this complex visual input made of a mixture of natural and artificial vision. The resulting effects of this position for perception and reasoning activities are described. The framework model of cognitive activities described in the previous course on mental images serves as a departure point. Then the following are discussed: (1) how humans solve the possible distorsions between sensors and human vision; (2) how these perceptive input are integrated into mental representations; (3) the central question of confidence into visual support-systems; and (4) the related consequences for workload. Author (revised)

N94-23982# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.
NIGHT VISION DEVICES AND CHARACTERISTICS
H. LEE TASK *In* AGARD, Visual Problems in Night Operations 8 p (SEE N94-23976 06-54) May 1992
(AGARD-LS-187) Copyright Avail: CASI HC A02/MF A01

Night vision goggles (NVG's) are widely used to enhance visual capability during night operations. NVG's are basically composed of an objective lens which focuses an image onto the photo-cathode of an image intensifier tube which in turn produces an amplified image that is viewed through an eyepiece lens. There are several versions of NVG's in use and in development. These include the AN/PVS-Five, AN/AVS-Six, PVS-Seven, Cat's Eyes, Nite-Op, Eagle Eyes, Merlin, and others. The first section of this paper provides a brief description and characterization of each of these NVG's. There are several parameters that are used to characterize the image quality and capability of NVG's. These parameters include field-of-view (FOV), resolution, spectral sensitivity, brightness gain, distortion, magnification, optical axes alignment, image rotation, overlap, beamsplitter ratio, exit pupil diameter, eye relief, and others. Each of these is discussed in the second section of this paper. Author (revised)

N94-23983# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.
COCKPIT/NVG VISUAL INTEGRATION ISSUES
H. LEE TASK *In* AGARD, Visual Problems in Night Operations 6 p (SEE N94-23976 06-54) May 1992
(AGARD-LS-187) Copyright Avail: CASI HC A02/MF A01

This paper is divided into two main sections: visual significance of night vision goggles (NVG) characteristics and cockpit/NVG integration issues. The first section deals with the relationship between the NVG characteristics discussed in the previous paper and visual capability. The second section explores several issues associated with successfully integrating the NVG with the aircraft cockpit for optimum system performance. Author (revised)

N94-23984# Aerospace Medical Research Labs., Williams AFB, AZ. Aircrew Training Research Div.
NIGHT VISION GOGGLE ILLUSIONS AND VISUAL TRAINING
WILLIAM E. BERKLEY *In* AGARD, Visual Problems in Night Operations 6 p (SEE N94-23976 06-54) May 1992
(AGARD-LS-187) Copyright Avail: CASI HC A02/MF A01

Night vision goggles (NVG's) possess certain specific visual characteristics related to their limited resolution, field of view and automatic gain control. In addition, the near infrared energy to which NVG's are most sensitive has somewhat different properties as compared to visible light. These factors combine to produce certain effects, limitations and illusions not ordinarily encountered with unaided vision. NVG visual training for aircrew members is conducted with didactic presentations, terrain board simulation, video tape presentations of intensified imagery, flight simulators utilizing computer generated imagery, and actual flight with NVG's. Computer based training and an interactive videodisc are under development. Derived from text

N94-28422# Norwegian Transarctic Expedition, His (Norway).
EVALUATION OF LIFE SUPPORT EQUIPMENT DURING AN UNSUPPORTED NORTH POLE EXPEDITION
W. GAUTVIK, J. O. OWE (Institute of Aviation Medicine, Oslo, Norway.), and T. A. OFTEDAL (Norwegian Defence Research Establishment, Kjeller.) *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 6 p (SEE N94-28420 08-51) Oct. 1993
(AGARD-CP-540) Copyright Avail: CASI HC A02/MF A03

This paper presents practical experience with the following life support equipment used during an unsupported North Pole expedition in 1992: clothing, sleeping bag with vapor barrier inner liner, a high efficiency cooking gear for melting water, and freeze dried food with 70 percent of the energy from fat. Derived from text

N94-28430# Guelph Univ. (Ontario). School of Engineering.
THE POTENTIAL OF NEW TEXTILES IN IMPROVING SURVIVAL PROSPECTS
K. SLATER *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 13 p (SEE N94-28420 08-51) Oct. 1993
(AGARD-CP-540) Copyright Avail: CASI HC A03/MF A03

The paper surveys briefly the role of textile materials in enhancing comfort and survival prospects, in both cold and hot climates, identifying the fiber, fabric and textile construction factors of critical importance. An examination of the interaction between these factors, showing how they enhance or interfere with one another, is also carried out in outline. Selected new textile fibers and fabric construction or finishing techniques are then analyzed to determine how their novel characteristics can improve their cold- or hot-weather performance, with a prediction in each case of how the advantages derived from their incorporation may potentially be of use in improving aircrew or ground support staff clothing applications. Derived from text

N94-28431# META Research, Inc., Richmond (British Columbia).
FIRE-RESISTANT WATER VAPOUR PERMEABLE BUOYANT INSULATION
WENDELL UGLENE and BRIAN FARNWORTH *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993 Sponsored by Mustang Survival and British Columbia Research Council
(AGARD-CP-540) Copyright Avail: CASI HC A02/MF A03

Compared to closed cell foam, constant wear garments designed with this material provide added comfort due to increased heat losses during sweating, shortened drying times after sweating, and added flexibility. Although introducing water vapor permeability causes a degradation to the material's cold water immersion protection, the integrity of its fire protection and buoyancy remains unaltered. Author

N94-28432# Gore (W. L.) and Associates, Inc., Elkton, MD.
DEVELOPMENT OF A NEW CHEMICAL WARFARE AGENT PROTECTIVE MATERIAL
S. NICHOLAS ALLEN, ROBERT J. BENDER, and TERRI L. KELLY *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993
(AGARD-CP-540) Copyright Avail: CASI HC A02/MF A03

In 1976 W. L. Gore & Associates, Inc. invented GORE-TEX fabric utilizing expanded polytetra-fluoroethylene (ePTFE). This was the first truly waterproof and moisture vapor permeable fabric laminate. In 1980 the company began to develop products for military applications. Since that time, Gore has supplied GORE-TEX fabric for, and assisted in the development of, some of the military's most technically sophisticated apparel: the U. S. Army's Extended Cold Weather Clothing System (ECWCS), the U. S. Navy's Over Water Flight Suit (OWFS), and the U. S. Air Force's Security Police Jacket being but a few examples. All of these garments provide the user with increased levels of protection from harsh environments and have proved themselves to be very durable. GORE-TEX fabric laminate has consistently proven itself to be technically superior to any other material. This paper details the

development by Gore of a new chemical warfare protective material based on proven ePTFE technology combined with a new highly activated polymer system (APS). Author

N94-28433# Alberta Univ., Edmonton (Alberta). Dept. of Human Ecology.

THERMAL PROTECTIVE PERFORMANCE AND INSTRUMENTED MANNEQUIN EVALUATION OF MULTI-LAYER GARMENT SYSTEMS

E. M. CROWN, M. Y. ACKERMAN, J. D. DALE, and K. B. RIGAKIS *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993 Sponsored by Canadian Petroleum Association and Defence Research Establishment

(AGARD-CP-540) Copyright Avail: CASI HC A02/MF A03

The purpose of this research was to evaluate the relative effectiveness of different clothing systems in their contribution to protection against exposure to high heat flux flash fires. All systems were exposed to controlled simulated flash fires (80 or 84 kW/sq m) on a thermally instrumented mannequin. The percentage of the mannequin surface reaching second and third degree burn criteria was recorded. In addition, the multiple layers of fabrics which were used together in each of the garment systems were tested according to a standard thermal protective performance (TPP) test. The protection provided by multiple layered garment systems was significantly greater than would be expected from the additive effects of the layers used singly. The outer layer of a garment system must be flame retardant, however; wearing a flammable garment over a flame retardant one clearly negates the benefits of the FR layer. While it cannot be concluded for certain that undergarments must also be flame retardant, results demonstrate that FR undergarments offer more protection than non-FR ones, especially when worn under the relatively light-weight fabrics which may be used for military flightsuits. Only in one experiment with garment systems comprising all-FR layers did small-scale TPP tests indicate the relative protection provided by the systems. The TPP test did not indicate the potential hazard of systems in which the outer layer is non-FR. Nor did it differentiate among the three different flight suit fabrics or demonstrate the relative protective performance of different underwear materials. Author (revised)

N94-28435# German Air Force, Fuerstenfeldbruk (Germany). Inst. of Aviation Medicine.

EFFECTIVENESS OF PROTECTION CLOTHING FOR COLD WEATHER CONDITIONS AFTER EJECTION OVER SEA: A CASE REPORT

B. MAYR and M. KRAEMER *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993

(AGARD-CP-540) Copyright Avail: CASI HC A02/MF A03

During a night formation mission including an approach without establishing a connection to the tanker aircraft a collision of both aircrafts, Typ PA 200 Tornado occurred. The four aircrew members performed an ejection. The site of the accident is located over the baltic sea in the Skagerrak region. At the time of accident, the air temperature was noted with 6 C, the water temperature with 11 C, and the sea with waves of 4 to 4.5 m height with a frequency of 8 waves per minute. The time of rescue ranged from 1 hour 28 minutes to 2 hours 14 minutes. This document reports on clothing and personal equipment, on the clinical findings, and on statements of the crew members. The crew member who was recovered after 2 hours and 14 minutes did not survive. This accident shows that with the ordered clothing, a survival under these conditions is supported, yet with incomplete equipment, it must be reckoned with a fatal outcome. Further details are discussed. Derived from text

N94-28436# Shark Group of Companies, Morpeth (England).

ADVANCED INTEGRATED COLD PROTECTION FOR AIRCREW

E. BRAMHAM and M. J. TIPTON (Surrey Univ., Guildford, England.) *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993

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In this paper, the concept of an Advanced Integrated Survival System is introduced and discussed in relation to the Helicopter Crew Member and Passengers, although the principles are equally applicable to many other types of user and circumstances requiring specialized protective clothing. The fundamental principles behind the concept are firstly that the wearer should be given protection against all of the hazardous responses associated with immersion in cold water and secondly, that the individual components which make up the integrated survival system (ISS) must be compatible and complementary. They may also be interdependent. Derived from text

N94-28437# Surrey Univ., Guildford (England).

EMERGENCY UNDERWATER BREATHING AIDS FOR HELICOPTER PASSENGERS AND CREW

M. J. TIPTON (Institute of Naval Medicine, Alverstoke, England.), E. BRAMHAM (Shark Group of Companies, Morpeth, England.), and D. H. ELLIOTT *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993 Sponsored by Shell Research Ltd. and Esso Research Center

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In this paper, the rationale for the provision of some form of helicopter emergency underwater breathing aid (HEUBA) for helicopter passengers and crew is briefly discussed and the thoughts and work which resulted in the production of a new aid, 'Air Pocket', is reviewed. Derived from text

N94-28443# Aerospace Medical Research Labs., Brooks AFB, TX.

AEROMEDICAL SUPPORT FOR CASUALTIES IN EXTREMELY HOT CLIMATES

S. A. NUNNELEY and R. U. BISSON *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 7 p (SEE N94-28420 08-51) Oct. 1993

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Aeromedical support for operations in hot climates involves exposure to acute heat injury and chronic heat stress which are unfamiliar to many medical personnel in NATO nations. Preparation for deployment to a hot climate should include review of climatic data for the site, appropriate adjustment to supplies and equipment needed to handle predicted numbers of heat casualties, and education of all air base personnel regarding methods of preventing heat illness. Medical facilities at the remote site may include local buildings or air transportable units. Special care is required with respect to housekeeping and provision of safe food and water in hot climates. Casualties arriving from remote sites should be assumed to suffer from heat stress and dehydration; those with elevated temperatures or disturbed consciousness must be treated as heat stroke cases until proven otherwise. Oral rehydration mixtures should be used whenever possible, reserving intravenous fluids for severe cases. Plans for air evacuation of all patients should attempt to minimize heat stress during loading and allow for continued rehydration in flight. Author

N94-28444# Spanish Air Force, Talavera AFB (Spain).

WORK CONDITIONS ASSESSMENT IN PILOTS AND GROUND PERSONNEL UNDER HIGH WEATHER TEMPERATURES

J. L. GARCIAALCON and J. M. MORENOVAZQUEZ (Extremadura Univ., Badajoz, Spain.) *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 9 p (SEE N94-28420 08-51) Oct. 1993

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Humans and animals often exhibit a remarkable ability to adapt to harsh or rapidly changing environmental conditions. One obvious means of adaptation is to move to where the environmental stresses are less severe. The body also has a great physiological capacity for adaptation. There exists ample literature on adaptative mechanisms and processes. When a person becomes acclimatized, the hypothalamus and other body control organs and systems settle into cooperative equilibrium, with certain chemical or hormonal levels that are appropriate for that particular season. The present study, describes how simple dietary rules can prevent involuntary dehydration brought about by sweating. Author (revised)

N94-28445# Royal Air Force, Farnborough (England). Inst. of Aviation Medicine.
THERMAL STRAIN GENERATED BY AN ENHANCED ANTI-G PROTECTION SYSTEM IN A HOT CLIMATE
P. J. SOWOOD and E. M. OCONNOR *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 13 p (SEE N94-28420 08-51) Oct. 1993
(AGARD-CP-540) Copyright Avail: CASI HC A03/MF A03

A flight trial was conducted at RAF Akrotiri to assess the level of thermal strain associated with, and the G protection provided by, the prototype European Fighter Aircraft (EFA) interim aircrew equipment assembly (AEA) in a warm climate. Six subjects flew a standardized sortie four times in the RAF IAM Hawk aircraft: two while wearing the EFA AEA, and two wearing standard Hawk Summer AEA. The sortie profile included simulated air combat and four high G turns. Cockpit temperatures, rectal and skin temperatures, heart rate, and sweat rate were recorded. Subjective thermal comfort, fatigue, and G tolerance were also assessed. Skin temperatures at the chest, back, and upper thigh sites and mean skin temperatures were greater in flight, and sweat rate was increased when the EFA AEA was worn. However, rectal temperature and heart rate did not differ significantly when the EFA AEA was worn indicating that homeostasis was maintained by thermoregulatory mechanisms. Superior G protection was provided by the EFA AEA. Taken as 8 whole, these findings suggest that wearing the EFA AEA in a warm climate is associated with an increased but not unacceptable level of thermal stress while offering greater G protection. These results may not generalize to conditions where ambient temperatures are higher or where more insulative protective clothing is required. Author (revised)

N94-28446# Royal Air Force, Farnborough (England). Inst. of Aviation Medicine.
IMPLICATIONS OF CLIMATIC EXTREMES IN AIRCREW NBC OPERATIONS
A. J. F. MACMILLAN *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 6 p (SEE N94-28420 08-51) Oct. 1993
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The NBC protective equipment and facilities in service with UK forces must be used when an appropriate threat exists irrespective of climate. Modifications to the individual assemblies, including provision of heated ventilating air to the aircrew respirator and additional insulation in cold conditions together with means to increase loss of body heat in hot climates and combined with changes to procedures and adaptation of concepts of use, can minimize the impedance to effective air operations which may occur from the additive effects of wearing NBC protective equipment in climatic extremes. Author (revised)

N94-28447# Army Research Inst. of Environmental Medicine, Natick, MA. Military Performance and Neuroscience Div.
THE ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE: ASSESSING REACTIONS TO ENVIRONMENTAL EXTREMES IN MILITARY OPERATIONS
JOHN L. KOBRICK, JAMES B. SAMPSON (Army Natick Research and Development Command, MA.), and RICHARD F. JOHNSON *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 8 p (SEE N94-28420 08-51) Oct. 1993
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The environmental symptoms questionnaire (ESQ) was developed to aid in the standardized assessment of symptoms experienced by individuals exposed to environmental extremes. It was used initially to delineate the symptoms of acute mountain sickness, but has since evolved into a more comprehensive tool for assessing subjective reactions to ambient heat and cold, to diet, physical exercise, and medications. The ESQ has also been made more reliable and user friendly by revision, addition and removal of certain items, and by compression of the initial scale values. Factor analysis of responses has identified several meaningful symptom clusters, and has provided a useful technique for scoring those clusters under both laboratory and field conditions. Studies utilizing the ESQ under various environmental extremes are summarized and reviewed. Current administration and scoring methods are presented. Author (revised)

N94-28451# Exotemp Systems, Inc., Stittsville (Ontario).
RECENT CANADIAN ADVANCES IN ACTIVE THERMAL PROTECTION
P. A. BROWNE *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 9 p (SEE N94-28420 08-51) Oct. 1993
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The Gulf war created an unusual incentive to the rapid development and deployment of active cooling systems for defense personnel. One of the most successful efforts in this respect concerned a liquid-circulating system which departed from prior art in a number of significant ways. The system was deployed first by Canadian aircrew, and then by their British counterparts in the later stages of the conflict. The systems used by these forces are described, with an account of their physical and thermal characteristics, and an account of their performance in the field. Very recent developments in electrically powered cooling units for microclimate use are also described. These new devices offer very real advantages in terms of power and space consumption. The impact they will have on air operations in extreme heat is discussed. Author

N94-28452# Institute of Aviation Medicine, Manching (Germany).
TEST OF A NEW PROTECTION SUIT IN A CLIMATIC CHAMBER
H. PONGRATZ, M. HARRE, B. KARMANN, A. RIECK, and H. VAIC *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 4 p (SEE N94-28420 08-51) Oct. 1993
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Within the framework of the research and technology program, a whole-body protection suit with integrated helmet was developed by the Dornier Company. The thermophysiological capabilities of this suit were tested by Division IV Ergonomics of the German Air Force Institute of Aviation Medicine. Ambient temperatures higher than those normally to be expected in the cockpit were chosen intentionally. In spite of this fact, pulse rates remained below the limiting value and the average rise in core temperature was insignificant. Loss of weight through sweating amounted to approximately 1% of body weight. It proved possible to remove 82% of this sweat by means of ventilation. Based on the results of the questionnaires on subjective sensibility, no prejudice to well-being and no negative effects in respect of the capability to act were established with regard to the testing of the whole-body protection suit under laboratory conditions. Author (revised)

N94-28453# Army Aeromedical Research Lab., Fort Rucker, AL.
THE USE OF LIQUID AND AIR MICROCLIMATE CONDITIONING SYSTEMS TO ALLEVIATE HEAT STRESS IN HELICOPTER NBC OPERATIONS
ROBERT THORNTON, J. LYNN CALDWELL, and FRANK GUARDIANI *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 23 p (SEE N94-28420 08-51) Oct. 1993
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The effects of microclimate cooling on aviator performance and physiology in Nuclear, Biological, and Chemical (NBC) Individual Protective Equipment (IPE) were evaluated in the USAARL UH-60 research flight simulator. Sixteen male aviators flew the simulator in two temperature conditions, 35 C and 41 C, both at 50% relative humidity (RH). Two thermoelectric conditioning units were used, one providing cooled blown air, the other cooled water to the aviators. At each temperature they flew for up to six hours in NBC IPE with no cooling, air cooling, and liquid cooling. Author (revised)

N94-34627# Sikorsky Aircraft, Stratford, CT. Crew Station Design.
EXPANDING THE PILOT'S ENVELOPE
BRUCE E. HAMILTON *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 6 p (SEE N94-34605 10-05) Mar. 1994
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Advances in aircraft technology have allowed the construction of fighters which can easily exceed the pilot's capability to react and to sustain G forces. Advances in avionics have allowed these airframes to be fitted with sensors, weapons, and data processors

to the point that the workload associated with mission accomplishment sometimes exceeds the pilot's capabilities. Consequently, some aircraft capabilities are rarely used due to lack of familiarity. These developments highlight the fact that the ability of the aircraft to fulfill its mission is dependent upon the pilot's utilizing its capabilities as an integrated weapon system. Pilots, like airframes, have operational envelopes and expanding the pilot's envelope allows fuller exploitation of the airframe's envelope and the avionics capabilities. The nature of the pilot's envelope is presented along with attributes of a pilot interface which support expansion of the pilot's envelope.
Author (revised)

N94-36336# Netherlands Aerospace Medical Centre, Soesterberg (Netherlands). Research Dept.
REVIEW OF HUMAN FACTORS PROBLEMS RELATED TO LONG DISTANCE AND LONG ENDURANCE OPERATION OF AIRCRAFT
RIES M. SIMONS and PIERRE J. L. VALK *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 9 p (SEE N94-36321 11-05) Nov. 1993
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Long distance operations are characterized by rapid multiple time-zone changes and long irregular work schedules. Performance and alertness of aircrew engaged in these operations might be affected by circadian disruptions, sleep loss, workload, and cockpit-environmental factors, such as lower pressure, low relative humidity, and constant background noise. Recent literature on the various factors, which contribute to fatigue and reduced alertness of pilots, is reviewed. Author

N94-36623# Naval Air Warfare Center, Warminster, PA. Aircraft Div.
ADVANCED HELMET TRACKING TECHNOLOGY DEVELOPMENTS FOR NAVAL AVIATION
JAMES H. BRINDLE *In* AGARD, Pointing and Tracking Systems 15 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A03/MF A02
There is a critical need across the Services to improve the effectiveness of aircrew within the crewstation by capitalizing on the natural psycho-motor skills of the pilot through the use of a variety of helmet-mounted visual display and control techniques. This has resulted in considerable interest and significant ongoing research and development efforts on the part of the Navy, as well as the Army and the Air Force, in the technology building blocks associated with this area, such as advanced head tracking technologies, helmet-mounted display optics and electronics, and advanced night vision or image intensification technologies. Advanced multi-mode visually-coupled systems combine the attributes of image intensification with those of the helmet-mounted display capabilities for symbology and thermal sensor presentation. Examples of this class of system could be something as simple as the night vision goggle HUD, or NVG-HUD, which combines head tracking, image intensification, and simple symbology overlay, to the more complex multi-mode systems with high resolution miniature CRT's. This class of systems is capable of presenting to the pilot correlated, spatially-referenced information from both the image intensification technology, as well as a dynamic, high fidelity symbology overlay, and correlated thermal sensor imagery.
Derived from text

N94-36624# General Electric Co. Ltd., Edinburgh (Scotland). Display Systems Group.
ADVANCES IN HELMET TRACKERS
W. M. ASPIN *In* AGARD, Pointing and Tracking Systems 4 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A01/MF A02
The object of this paper is to describe in general, some recent developments in helmet tracking devices and, to detail the design of a particular optically based system. Author

N94-36632# Alenia Aeronautica, Turin (Italy). System Technology Dept.
STUDIES AND SIMULATIONS ON SENSOR FUSION AND CUEING FOR FIGHTER APPLICATION
M. AVALLE *In* AGARD, Pointing and Tracking Systems 8 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02
A method to implement the sensor fusion and sensor cueing on an advanced fighter aircraft is described in this paper. Starting from a short introduction concerning the general aspects and theory of sensor fusion, the paper presents some choices adopted during the development of the sensor fusion process at ALENIA DVD System Technology Dept. Sensor cueing will be also introduced and some particular cases of interest for a fighter aircraft will be discussed. The performances of the adopted solutions are then discussed on the basis of some experimental results obtained using a simulation tool. An evaluations of the overall sensor fusion process performance and some considerations about possible alternatives will conclude the work. Author

N94-37262# Syracuse Univ., NY. Center for Science and Technology.
TASK-SPECIFIC USABILITY REQUIREMENTS FOR VIRTUAL INFORMATION ENVIRONMENTS: INTERFACE DESIGN AND DATA REPRESENTATION FOR HUMAN OPERATORS OF COMPLEX MEDICAL SYSTEMS
MICHAEL S. NILAN *In* AGARD, Virtual Interfaces: Research and Applications 8 p (SEE N94-37261 12-53) May 1994 Sponsored in part by New York State Center for Advanced Technology in Computer Applications and Software Engineering; Alex Nason Foundation of New York City; and AFOSR
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The National Research Council has identified 'usability' as one of two major requirements for coherent development of computer and information systems over the next ten years. The use of multisensory virtual environment technology to display and provide access to system functions and data relevant to large-scale, complex, potentially volatile medical tasks (e.g., telepresence surgery) increases the (already critical) need for unobtrusive, transparent interface designs, and data representations. Unfortunately, the medical community must take responsibility for providing requirements specifications to the computer industry or else be forced to adapt to existing technical constraints. Recent research in interface design and data organization/representation for two dimensional computer applications indicates that dynamic representations of the specific task or problem that the human operator is performing is very effective. Employing a task-specific, 'user-based' methodology, steps in the task resolution are organized into a dynamic model of the task. Linked to this model are the functional system requirements and information/data need requirements divided into specific content requirements, display requirements (including spatial organization) and system help requirements. The resultant model is readily interpretable by system designers and in addition, provides them with specific task-related system evaluation criteria. Usability advantages of dynamic task representations include: minimal system/application training requirements for operators; and coherent, comprehensible, and uncluttered sensory field organization of system functions, relevant data, and help information. Because of its ability to provide specific task-related requirements to system designers, this methodological approach will insure maximum usability of high performance computing (including virtual reality technology) for critical medical applications. Author

N94-37264# Physics and Electronics Lab. TNO, The Hague (Netherlands). High Performance Computing.
ON THE FEASIBILITY OF VIRTUAL ENVIRONMENTS IN MEDICINE
A. C. M. DUMAY and G. J. JENSE *In* AGARD, Virtual Interfaces: Research and Applications 8 p (SEE N94-37261 12-53) May 1994
(AGARD-CP-541) Copyright Avail: CASI HC A02/MF A02
Virtual Environments (VE) allow a human to interact with a (computer) system in such a way that a high level of presence in a computer-synthesized world is experienced. In principle, all human senses are involved with the interaction. Many applications may benefit from this type of human-machine interfacing, however, little have emerged so far for medicine. In this paper, we elaborate on

some realistic potential applications of virtual environment technology in the field of medicine. These applications can be found in education/training, therapy, surgery, rehabilitation, diagnosis, telemedicine, and biomechanics. The value to be added to these applications by VE technology lies in the fact that patient data or patient models may be moderated to the physician in a more intuitive and natural manner. Despite these potentials, the short-term feasibility of these applications can be put into question for various reasons. Firstly, the current generation of display devices have a resolution that may show to be too low to achieve a sufficiently high degree of realism for medical applications. Secondly, there are no commercially-available actuators for tactile and force feedback which the physician desperately need for the simulation of the contact with the (virtual) patient. Thirdly, the enormous computing power required for these applications needs (yet) a considerable investment. With these limitations in mind, we believe that we are at the cradle of a whole new generation of VE applications in medicine. Author

N94-37266# Sextant Avionique, Saint Medard en Jalles (France).

INTERACTIVE LARGE SCREEN: A MULTI-MODE DIALOGUE TOOL FOR FUTURE COCKPITS [LE GRAND ECRAN INTERACTIF: UN OUTIL DE DIALOGUE MULTIMODAL POUR LES FUTURES CABINES DE PILOTAGE]

B. BARBIER, E. FILIATRE, and I. IRIGARAY *In* AGARD, Virtual Interfaces: Research and Applications 4 p (SEE N94-37261 12-53) May 1994 In FRENCH

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The experimental make-up described here is constituted of a large size projection screen displaying an image on which an operator acts in real time, under control of a specific dialogue software, using several control devices (speech recognizer, numeric data glove, oculometer). Various human communication channels are then simultaneously used: vision and audition for the system-to-man flow; voice, gesture, and gaze for the man-to-system flow. Various ways of using and associating these communication channels allow to elaborate a multimodal dialogue. Author

N94-37267# Groningen Rijksuniv. (Netherlands). Traffic Research Centre.

IMMERSIVE VIRTUAL ENVIRONMENTS AS TRAINER: SYSTEM DESIGN FROM A COGNITIVE STANCE

M. WIERDA, P. C. VANWOLFFELAAR, and W. VANWINSUM *In* AGARD, Virtual Interfaces: Research and Applications 6 p (SEE N94-37261 12-53) May 1994 Sponsored by Ministry of Transport and Public Works

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Many of today's training-simulators for guiding, steering, or flying a vehicle are designed to have a safe, environmentally clean, flexible and cost effective educational environment. It is claimed that the training effectiveness can be increased significantly if the starting point of the design would be shifted from the 'enabling technology' position to a cognitive approach of the task to be learned in the simulator. An outline is given of this approach, encompassing a behavioral task-analysis, a cognitive process model, and an analysis of the educational goals in terms of cognitive and perceptual skills. It is concluded that knowledge in the domains of cognitive science and artificial intelligence is hardly used while this knowledge may bring about training simulators of a significantly other quality. Author

N94-37269# Defence Research Agency, Farnborough, Hampshire (England). Flight Systems Dept.

THE DRA VIRTUAL COCKPIT RESEARCH PROGRAM

JUDITH INESON *In* AGARD, Virtual Interfaces: Research and Applications 12 p (SEE N94-37261 12-53) May 1994 Sponsored by Ministry of Defence

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The aim of this paper is to describe work in progress at the Defence Research Agency (DRA) Farnborough on the Virtual Cockpit, with particular emphasis on format design and development. The paper reviews the reasons why the concept of the Virtual Cockpit is of interest, and the ways in which it differs from the common understanding of Virtual Reality. The potential advantages and disadvantages of such a man-machine interface are discussed. The overall aims of the DRA Virtual Cockpit research program are listed, together with a more detailed discussion of the areas of concern in the presentation of visual information. The current status of the research program is described. The hardware being used for this program comprises a head-coupled binocular helmet-mounted display (HMD) system in a skeletal cockpit rig with stereoscopic, computer generated graphics, and a set of demonstration formats showing examples of the type of imagery which might be employed in a Virtual Cockpit. This is followed by a description of APHIDS (Advanced Panoramic Helmet Interface Demonstrator System) - a more capable Virtual Cockpit research rig currently being built for DRA, and of its strengths and limitations. The paper concludes with an outline of how APHIDS will be employed in the next stage of the research program. Author

N94-37270# DIVISION Ltd., Almondsbury, Bristol (England).

VIRTUAL REALITY EVOLUTION OR REVOLUTION

CHARLES GRIMSDALE *In* AGARD, Virtual Interfaces: Research and Applications 4 p (SEE N94-37261 12-53) May 1994

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There is a growing body of research which can now lead us to a strong rationale for Virtual Reality as the next generation of Human Computer Interface. As an interface metaphor Virtual Reality clearly has great potential, throughout industry, commerce, and leisure. But how will it gain acceptance. It is my belief that this will be a process of evolution rather than revolution. Much has been written about the limitations of underlying computer systems, and 3D peripherals but there is a fundamental need for more powerful and flexible software upon which to build this new generation interface. Author

N94-37271# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.

MANUAL TRACKING PERFORMANCE USING A VIRTUAL HAND CONTROLLER: A COMPARISON STUDY

ROBERT G. EGGLESTON, WILLIAM P. JANSON, and SRIDHAR ADAPALLI *In* AGARD, Virtual Interfaces: Research and Applications 7 p (SEE N94-37261 12-53) May 1994

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This study compares a virtual hand controller (magnetic sensor attached to a glove) with a physical displacement stick in a single-axis manual control task. Three different control/display (C/D) ratios were used with each controller. Control performance was found to vary significantly with C/D ratio. When across-device comparisons were made at identical C/D ratios, a slight but significant performance advantage was found for the displacement stick at one C/D level. When between-device comparisons were made on the basis of a performance matching technique, the results were comparable for the virtual and physical hand controllers. The issue of how to best match test conditions to achieve an unbiased comparison of control devices is addressed. Arguments are advanced in favor of using the performance based matching technique. From this perspective, the data are interpreted to support the claim that comparable manual control performance can be achieved with a virtual hand controller. Author

N94-37272# Mooij and Associates, Oegstgeest (Netherlands).

A NON-INTRUSIVE WAY TO MEASURE POINT-OF-GAZE

G ZON, D. R., H. A. MOOIJ, and J. BOUWENS *In* AGARD, Virtual Interfaces: Research and Applications 8 p (SEE N94-37261 12-53) May 1994

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OBSERVER is an instrument for obtaining data about where a subject is looking on fixed user specified surfaces. Since the processing of data takes place in real time, this instrument can be used to indicate areas of interest just by looking at them. In this paper, after an introduction on the application of point-of-gaze (POG) data, the OBSERVER system is described. Attention is given to subsystems as well as to calibration. As the first application of OBSERVER, that of a measuring instrument, an 'eye-witness quality experiment' is discussed. Author

N94-37273# SR Research, Toronto (Ontario).
OPERATOR GAZE POSITION CONTROL INTERFACES: INVESTIGATION OF PSYCHOPHYSICAL AND OPERATIONAL PARAMETERS
DAVE M. STAMPE, EYAL M. REINGOLD, and JULIUS J. GRODSKI *In* AGARD, Virtual Interfaces: Research and Applications 9 p (SEE N94-37261 12-53) May 1994
(AGARD-CP-541) Copyright Avail: CASI HC A02/MF A02

Real-time monitoring of an operator's gaze position on a computer display of response options may form an important element of future computer interfaces and teleoperation control systems. In one implementation, the gaze position can serve as a pointer, and a critical length of gaze serves as selection, leaving the operator's hands free for other tasks. Control tasks such as multiple option selection, or looking for targets embedded within a picture are especially suited to selection by gaze position monitoring, since the search usually terminates on the object to be selected. More complex control functions can be implemented through multilevel 'menus' of choices. In the past, gaze monitoring systems restricted operator movement or required head restraints. The newest generation of gaze tracking systems allow free head movement and accurate gaze position monitoring over extended periods and are highly suited for control applications. Although gaze position control systems have been tried with moderate success in the past, little systematic investigation of the human parameters of gaze position control has been performed. In the present research program, important parameters of gaze selection such as fixation position accuracy, selection error rates, and the effects of real-time gaze position feedback were investigated. Experimental results will be used to suggest guidelines for creation and use of gaze position response in control interfaces. Author

N94-37274# Centre d'Essais en Vol, Bretigny-sur-Orge (France). Lab. de Medecine AeroSpatiale.
GAZE ORIENTATION UNDER G(Z)-LOAD. METHODOLOGICAL ASPECTS: PRELIMINARY RESULTS [ORIENTATION DU REGARD SOUS FACTEUR DE CHARGE. ASPECTS METHODOLOGIQUES: RESULTATS PRELIMINAIRES]
PATRICK B. SANDOR, ISABELLE HORTOLLAND, FREDERIC POUX, and ALAIN LEGER *In* AGARD, Virtual Interfaces: Research and Applications 7 p (SEE N94-37261 12-53) May 1994 In FRENCH
(AGARD-CP-541) Copyright Avail: CASI HC A02/MF A02

Gaze in head-free condition was computed under G(sub z)-load. Eye movements were measured with an oculometer using the pupil-to-corneal reflex method. Head movements were measured with an electro-optic system. The subject's head was at the center of a hemisphere (diameter 1.80 m). The internal face of this hemisphere was forming a screen on which a laser spot was to be projected. The subject's line-of-sight was computed, i.e. the direction of the eyeball in the head frame, which is mobile relative to the space. A procedure of correction of the parallax error allowed the determination of the point-of-gaze, which is the intersection point of the LDV with the screen. After static validation, two pilot experiments were performed under low G(sub z)-load. Results showed feasibility of the method in the experimental environment, and pursuit errors were quantified. Improvements are proposed. Author

N94-37275# British Aerospace Aircraft Group, Bristol (England). Human Factors Dept.
A COMPARISON OF TWO EXAMPLES OF MAGNETIC TRACKER SYSTEMS
M. WILLIAMS *In* AGARD, Virtual Interfaces: Research and Applications 19 p (SEE N94-37261 12-53) May 1994
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This paper is an account of an investigation of the performance of various position measuring devices which use low frequency AC or pulsed DC magnetic fields. They are used in many applications in computer graphics, and now for virtual reality, where it is necessary to estimate the observer's direction of gaze. As part of the Sowerby Research Center's program of eye movement research one such system is being integrated with a video based eye-tracker. There seems to be no independent, published assessment covering all aspects of all the systems which are of interest to this research program. This paper aims to fill that gap: it includes information relating to the static performance of two measuring systems: the 3-Space Polhemus Tracker and the Ascension Technologies' 'Bird'. The measurements relate to repeatability, noise, cross-talk, stability, range, and linearity. The influence of metal objects close to the transducers is also investigated. In most respects the 'Bird' sensor was found to be more appropriate for this application. Author

N94-37281*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE USE OF A TACTILE INTERFACE TO CONVEY POSITION AND MOTION PERCEPTIONS
A. H. RUPERT (Naval Aerospace Medical Research Lab., Pensacola, FL.), F. E. GUEDRY (Naval Aerospace Medical Research Lab., Pensacola, FL.), and M. F. RESCHKE *In* AGARD, Virtual Interfaces: Research and Applications 7 p (SEE N94-37261 12-53) May 1994 Sponsored by Naval Medical Research and Development Command
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Under normal terrestrial conditions, perception of position and motion is determined by central nervous system integration of concordant and redundant information from multiple sensory channels (somatosensory, vestibular, visual), which collectively yield vertical perceptions. In the acceleration environment experienced by the pilots, the somatosensory and vestibular sensors frequently present false information concerning the direction of gravity. When presented with conflicting sensory information, it is normal for pilots to experience episodes of disorientation. We have developed a tactile interface that obtains vertical roll and pitch information from a gyro-stabilized attitude indicator and maps this information in a one-to-one correspondence onto the torso of the body using a matrix of vibrotactors. This enables the pilot to continuously maintain an awareness of aircraft attitude without reference to visual cues, utilizing a sensory channel that normally operates at the subconscious level. Although initially developed to improve pilot spatial awareness, this device has obvious applications to 1) simulation and training, 2) nonvisual tracking of targets, which can reduce the need for pilots to make head movements in the high-G environment of aerial combat, and 3) orientation in environments with minimal somatosensory cues (e.g., underwater) or gravitational cues (e.g., space). Author

N95-14263# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
THE MUSCULOSKELETAL AND VESTIBULAR EFFECTS OF LONG TERM REPEATED EXPOSURE TO SUSTAINED HIGH-G [LES EFFETS MUSCULOSQUELETTIQUES ET VESTIBULAIRES DE L'EXPOSITION REPETEE ET PROLONGEE AUX FACTEURS DE CHARGE ELEVES SOUTENS]
May 1994 70 p
(AGARD-AR-317; ISBN-92-835-0745-2) Copyright Avail: CASI HC A04/MF A01

Medical concerns of mechanical loading of biological systems during repeated sustained acceleration exposure of high performance aircraft were expressed during an AGARD conference of 24th-28th April 1989 (AGARD-CP-471) entitled 'Neck Injury in Advanced Military Aircraft Environments'. Biological systems of primary concern were direct effects on the spine causing neurological injury and on the otoliths of the vestibular system causing disorientation related pathologies. In addition, secondary vestibular effects can occur from cervical pathologies. The technical evaluation and overview of that conference expressed concerns that 'large gaps exist in our clinical and biomechanical knowledge of the problems of neck injury in high performance aircraft'. Advisory Report (AR) 317 addresses those concerns with an in-depth review of available pertinent information with recommendations on several courses of action directed towards the spine and vestibular systems. Specific topics covered include: (1) the physical environment of aerial combat maneuvers; (2) anatomy and biomechanics of the spine; (3) G-loading effects on the musculoskeletal system of the spine including risk factors and the prevention of injuries; (4) imaging considerations; (5) high sustained G effects on the vestibular system and methods to test organ dysfunctions; and (6) topical research proposals. Recommendations include: (1) study requirements; (2) aircrew selection training and education; (3) equipment modifications and development; and (4) research requirements. AR 317 contains 215 references. Author (revised)

N95-14949# Massachusetts Inst. of Tech., Cambridge, MA.
HUMAN FACTORS CONSIDERATIONS FOR REMOTE MANIPULATION
THOMAS B. SHERIDAN *In* AGARD, Advanced Guidance and Control Aspects in Robotics 24 p (SEE N95-14942 03-63) Jun. 1994
(AGARD-LS-193) Copyright Avail: CASI HC A03/MF A03

This paper presents human factors considerations of remote manipulation, sometimes called teleoperation. The paper reviews two broad classes of sensing and display considerations, namely (1) vision and video feedback, and (2) haptic sensing and display, including force and touch feedback from remote manipulators. Next 'telepresence' and virtual environments are discussed in relation to one another. The paper then discusses two broad classes of teleoperator control, namely (1) direct manual control and (2) supervisory control. Finally the paper considers briefly the subjects of cognition and mental models as they relate to remote manipulation. Author (revised)

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COMPUTER OPERATIONS AND HARDWARE

Includes hardware for computer graphics, firmware, and data processing.

N92-32183# Defence Research Information Centre, Glasgow (Scotland).
LOCAL AREA NETWORKS (LAN)
G. FARQUHAR *In* AGARD, Bringing Down the Barriers to Information Transfer 7 p (SEE N92-32182 22-82) Feb. 1992
(AGARD-CP-505) Copyright Avail: CASI HC A02/MF A02

The discussion is confined to the Man Machine Interface problems encountered during implementation and post implementation. Various development aspects are considered, commencing with the definition of the users' requirement, as distinct from the users' wishes, to the provision of adequate post implementation support. The LAN installed at the Defence Research Information Center (DRIC) during 1987 and subsequently enhanced in 1988 is taken as the model for the discussion. Author

N92-32440# Naval Weapons Center, China Lake, CA. Attack Weapons Dept.
GENERIC MODULAR IMAGING IR SIGNAL PROCESSOR
JOHN ERIC AUBORN and WILLIAM HARRIS *In* AGARD, Integrated Target Acquisition and Fire Control Systems 6 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A02/MF A02; 1 functional color page

We have developed a modular signal processor architecture that is suitable for many applications to meet real time requirements and adaptable to multiple uses. This generic modular architecture was developed and demonstrated in real time hardware for representative filters and a target detection algorithm. Computer aided design tools were used throughout the hardware development. An application specific integrated circuit (ASIC) or other custom IC implementation can be used for actual production hardware. Author

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COMPUTER PROGRAMMING AND SOFTWARE

Includes computer programs, routines, and algorithms, and specific applications, e.g., CAD/CAM.

N92-25980# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
AUTOMATED SOFTWARE GENERATION APPROACHES FOR THE DESIGN AND DEVELOPMENT OF GUIDANCE AND CONTROL SYSTEMS SOFTWARE [LES DIFFERENTES APPROCHES GENERATION POUR LA CONCEPTION ET LE DEVELOPPEMENT DE LOGICIELS DE GUIDAGE ET DE PILOTAGE]
EDWIN B. STEAR, ed. (Boeing Co., Seattle, WA.) and JOHN T. SHEPHERD, ed. (GEC-Marconi Ltd., Borehamwood, England) Mar. 1992 188 p
(AGARD-AR-292; ISBN-92-835-0663-4; AD-A252184) Copyright Avail: CASI HC A09/MF A02

This advisory report summarizes the findings and conclusions of Working Group 10 of the Guidance and Control Panel of AGARD, the terms of reference which were: (1) to develop and consider a set of requirements for application of software generators for guidance control systems, (2) to evaluate the characteristics and capabilities offered by existing application software generator technology with respect to the requirements defined in (1), and (3) if required, to determine the modifications and improvements necessary for such technology to meet the requirements defined in (1). The working group defined and investigated four approaches to software generation: reusable software modules, expert systems, program transformation techniques, and fourth generation languages. Author

N92-27903# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain). Lab. de Guiado.
FUZZY GUIDANCE SYSTEM EVALUATION
J. R. MARTIN, F. SANCHEZ, P. V. CUENCA, L. M. RODRIGUEZ, and J. B. ECIJA *In* AGARD, Air Vehicle Mission Control and Management 15 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

A study is described that compares the capability of a fuzzy logic controller with a classical controller P+D (proportional plus derivative). The model used for this investigation is the attitude control of a microsatellite launcher, during the first stage of flight. This model has been chosen because it performs on a very unstable plant; the launcher is conceived without stabilization surfaces and only the body is considered as a generator of aerodynamics forces. Movable-nozzle Thrust Vector Control (TVC) will be used as a flight control device. The problem is studied under three degrees of freedom simulation at two levels, software and hardware. The concept formulated in this work is the analysis of the fuzzy rules that perform robust control during the flight. It has been used on perturbations, a wind profile and misalignments in the launcher. The wind model generates a wind velocity vector, which is constant throughout each run. The wind velocity vector is parallel to the surface of the earth. Author

N92-27907*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
FROM AN AUTOMATED FLIGHT-TEST MANAGEMENT SYSTEM TO A FLIGHT-TEST ENGINEER'S WORKSTATION
E. L. DUKE, R. W. BRUMBAUGH, M. D. HEWETT, and D. M. TARTT (G and C Systems, Inc., San Juan Capistrano, CA.) *In* AGARD, Air Vehicle Mission Control and Management 12 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

Described here are the capabilities and evolution of a flight-test engineer's workstation (called TEST PLAN) from an automated flight-test management system. The concept and capabilities of the automated flight-test management system are explored and discussed to illustrate the value of advanced system prototyping and evolutionary software development. Author

N92-32443# Naval Weapons Center, China Lake, CA. Attack Weapons Dept.
TARGET DETECTION USING CO-OCCURRENCE MATRIX SEGMENTATION AND ITS HARDWARE IMPLEMENTATION
JOHN ERIC AUBORN and JAMES M. FULLER *In* AGARD, Integrated Target Acquisition and Fire Control Systems 4 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A01/MF A02; 1 functional color page

Our goal was to develop a method for detection of man-made targets in infrared (IR) scenes. The application required detection to be independent of the polarity of the image and independent of the rotation. The approach had to be realizable in real time hardware and compatible with size and weight restraints. We made a laboratory demonstration of the detection algorithm using a general purpose image processor. The resultant demonstration showed the capability of detecting targets. Real imagery was used and the results were promising. We made an architectural design to implement the algorithm in hardware, simulated the feasibility of the approach, and made a detailed hardware design. A prototype system was fabricated and tested. Author

N93-19763# Telefunken System Technik G.m.b.H., Ulm (Germany).
TICAMS: TELEFUNKEN INTEGRATED COMPUTER-AIDED MAINTENANCE SYSTEM
WERNER WURSTER *In* AGARD, Advanced Aircraft Interfaces: The Machine Side of the Man-Machine Interface 18 p (SEE N93-19757 06-54) Oct. 1992
(AGARD-CP-521) Copyright Avail: CASI HC A03/MF A03

In view of ever decreasing budgets, the Aspect Life Cycle Cost (LCC) of a product is gaining in importance. Telefunken Systemtechnik has been working for more than 10 years in the area of Integrated Logistic Support with the aim of minimizing the LCC for new products. TICAMS is one result of this work. TICAMS is a general test system for development, production, and utilization phases. This universal concept automatically provides the practical and theoretical knowledge of each phase while minimizing costs. In doing so, the overall system requirements with regard to the user are supported by TICAMS thus leading to cost minimization in the utilization phase. TICAMS supports the user in conducting maintenance and repair work, optimizes essential tests and diagnosis procedures during the test procedure, and supports the user during each of the work stages by means of a comprehensive user interface and information system. TICAMS uses test strategies specified to the product which is to be tested and maintained, and works with an expert system for optimizing the diagnosis and test. Author

N93-19923# Naval Air Warfare Center, China Lake, CA.
DEVELOPMENT AND FLIGHT TESTING OF THE MULTI-SOURCE INTEGRATION ALGORITHMS IN THE F/A-18 MISSION COMPUTER SOFTWARE
J. J. CRUTCHFIELD *In* AGARD, Flight Testing 5 p (SEE N93-19901 06-05) Oct. 1992
(AGARD-CP-519) Copyright Avail: CASI HC A01/MF A04

This paper presents the newest innovation in air-to-air weapons employment capabilities, Multi-Source Integration (MSI). The integrating of a diverse suite of sensors on the F/A-18 Hornet has been the most significant avionics development effort attempted on a modern operational tactical aircraft. MSI is incorporated as statistical algorithms which merge spatial kinematic and identification data from the suite of sensors on board the aircraft. This merged data becomes trackfiles which are displayed to the pilot for the prosecution of an attack. Author

N93-22022# Computing Devices Co., Ottawa (Ontario). Ground Systems Div.
MULTI-WINDOW REGISTRATION ALGORITHM FOR AUTOMATIC DETECTION AND TRACKING OF MOVING TARGETS
P. CHURCH and T. GAJDICAR *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 7 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A02/MF A02

Image registration is an important preprocessing step often used in applications, such as automatic target tracking, to decouple image motion from target motion. This paper presents an image registration algorithm designed for a real-time implementation on platforms such as precision guided weapons. The algorithm uses a set of small optimal windows to register successive images from a video sequence. The windows are tracked over time and assessed for their quality in providing a good and persistent registration measure. Areas selected over moving objects are also detected and replaced. The image motion vectors obtained from each window are used to estimate the image motion correction. Evaluation of the performance of the algorithm in critical areas, such as its expected registration accuracy and its tolerance to image deformation caused by rotation, are presented. Results are presented when the algorithm is applied, in conjunction with a motion tracker, to the detection and tracking of targets in video sequences acquired from moving platforms and presenting difficulties of partial occlusion, high background clutter and low target-to-background contrast. The registration algorithm has demonstrated properties of robustness and computational efficiency that are of interest for guided weapons applications. The limitations of the method are also discussed. Author

N94-11338# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Munich (Germany). Inst. of Aeroelasticity.
ADAPTIVE ALGORITHMS FOR USE WITH DIGITAL FILTERS IN VIBRATION CONTROL
R. WIMMEL *In* AGARD, Smart Structures for Aircraft and Spacecraft 5 p (SEE N94-11317 01-24) Apr. 1993
(AGARD-CP-531) Copyright Avail: CASI HC A01/MF A04

Digital filters can easily be used to alter signal flows. As long as the desired transfer function of the filter is causal, a great variety of responses is made possible by appropriate choice of filter coefficients. To make use of this property in vibration control, algorithms should automatically change the filter coefficients to meet any given objective. A class of adaptive algorithms which search the gradient of a given performance function is described. In order to illustrate the requirements of adaptive structures, such as structurally conformed design, the feed-forward control environment serves as an example for applying these algorithms. Author (revised)

N94-29315# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
AEROSPACE SOFTWARE ENGINEERING FOR ADVANCED SYSTEMS ARCHITECTURES [L'INGENIERIE DES LOGICIELS POUR LES ARCHITECTURES DES SYSTEMES AEROSPATIAUX]
Nov. 1993 333 p In ENGLISH and FRENCH Symposium held in Paris, France, 10-13 May 1993
(AD-A277101; AGARD-CP-545; ISBN-92-835-0725-8) Copyright Avail: CASI HC A15/MF A03

During the past decade, many avionics functions which have traditionally been accomplished with analogue hardware technology are now being accomplished by software residing in digital computers. The purpose of this Symposium was to bring together military aerospace software experts from all NATO countries to share the results of their software research and development and virtually every aspect of software was considered with the following representing a partial set of topics: Aerospace Electronics Software Specification, Software Design, Programming Practices and Techniques, Software Validation and Testing, Software Management and Software Environments. For individual titles, see N94-29316 through N94-29349.

N94-29318# Shape Technical Center, The Hague (Netherlands).
DESIGNING AND MAINTAINING DECISION-MAKING PROCESSES
ANDREW BORDEN *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 6 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The design of the optimal strategy for decision making is intractably difficult when information sources (sensors) provide different amounts of information and have different costs associated with their use. This paper describes a sub-optimal design algorithm which can be further simplified if the user specifies some parts of the decision process to be executed at run-time. The design algorithm is provided with diagnostics so that the result can be compared with accuracy and response time requirements, and a

learning module which enables new information to be incorporated into the knowledge base. The complexity of this algorithm is compared to that of the optimal design algorithm. Author

N94-29319# Thomson-CSF, Malakoff (France).
EMBEDDED EXPERT SYSTEM: FROM THE MOCK-UP TO THE REAL WORLD
FREDERIC CAGNACHE *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 7 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

This paper is presenting a methodology for the integration of an expert system in an embedded real time software running the VRTX operating system. We define the 'Expert Unit' concept and its life cycle referring to a real experimentation. The production of operational embedded expert system becomes a reality because of the use of efficient tools and an original methodology for its integration. This paper is showing how software engineering techniques and methods (Life-Cycle definition, identification of generic configuration items) can help an embedded expert system development to be more efficient and controllable than by using the Boehm's spiral model. This Life-Cycle is compatible with military quality standards (GAM T17 and DOD 2167a). Derived from text

N94-29320# Dassault-Breguet Aviation, Saint-Cloud (France). Div. des Etudes Avancees.
FLIGHT COMMAND SOFTWARE DEVELOPMENT: RAFALE STUDIES [LE DEVELOPPEMENT DES LOGICIELS DE COMMANDES DE VOL, L'EXPERIENCE RAFALE]
D. BEURRIER, F. VERGNOL, and PH. BOURDAIS *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 13 p (SEE N94-29315 08-61) Nov. 1993 In FRENCH
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

After the introduction of the RAFALE's Flight Command System (Systeme de Commande de Vol: SCV). DASSAULT Aviation presents its studies on software applications to critical safety systems, with an emphasis on the following: (1) The methodology used in the development. It includes a phase for the formalization of the software specifications, its objective being to improve on the dialogue between two distinct entities: the automaticians on one hand and the computer programmers on the other hand. (2) The key support systems used in this methodology: GISELE: specification tool using a formal language whose testing and automatic prototype potential guarantee a descriptive quality, and VALIRAF: validation tool which automatically compares the results of the system to the models obtained during the studies on specifications. It manages the testing process and evaluates its level of reliability. An assessment of the results and a presentation of future programs of study are also included. Author (revised)

N94-29321# Alenia Spazio S.p.A., Turin (Italy).
OBJECT VERSUS FUNCTIONAL ORIENTED DESIGN
P. OCCELLI *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 9 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

Since the early Eighties the Object Oriented approach to software system development was proposed as a possible solution of the so called 'software crisis'. The claimed benefits were that Object Oriented Design (OOD) had the potential to improve software quality by making possible a direct and natural correspondence between the real world and its model. Many variants of the original approach were proposed and the new trend was spread across the Software Engineering community. The 'traditional' functional oriented methods were suddenly considered out of date and not appropriate to support development of large real time systems. There were, of course, some drawbacks but they were always attributed to method immaturity and poor tool support, two self-solving problems as time passed. Ten years or more have gone since then and OOD methods have been widely adopted for the development of large distributed real time systems. Are the lessons learnt from such projects according to the expectations? Are Functional Oriented methods still able to support software projects of the size required by the Aerospace industry in the years leading to the 2000? This paper proposes a possible answer to these questions comparing the pro and cons of both methods. This comparison will be carried out on issues like transition from requirements to design and to Ada code, traceability from requirements to design, software safety, software maintainability, software testing and relationship with DOD-STD-2167. Derived from text

N94-29322# Steria Mediterranee, Vitrolles (France).
HIERARCHICAL OBJECT ORIENTED DESIGN (HOOD): POSSIBILITIES, LIMITATIONS, AND CHALLENGES
PATRICE M. MICOUIN and DANIEL J. UBEAUD *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 8 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The goal of this article is to sketch a first evaluation after almost four year usage of the Hood methodology in the context of Ada real time software systems. For this purpose, it is made up of four parts: First, we will give a brief outline of Hood methodology. Secondly we quickly sketch out four years of Hood usage. Thirdly, we will summarize the main lessons learned throughout this experience. Fourthly, we will outline some directions useful to follow-up in the future. Author

N94-29325# Electronic System G.m.b.H., Munich (Germany). Elektroniksystem-und Logistik.
EXPERIENCES WITH THE HOOD DESIGN METHOD ON AVIONICS SOFTWARE DEVELOPMENT
W. MALA and E. GRANDI *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 12 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

HOOD represents one of the most interesting approaches of the recent years to support an object oriented SW design for large embedded systems written in Ada. This paper reports about experiences gained by the authors in the context of a current large European avionic development project, where the Ada SW design has been performed using HOOD Version 3.0. A simplified example describes the approach taken in the project for SW architectural design. A critical evaluation of the HOOD method follows, where advantages and disadvantages are discussed and some hints are given to overcome some identified weak areas. The paper concludes with the recognition of HOOD as a promising approach and encourages further discussion to remove the weak areas. Derived from text

N94-29326# Aerospatiale Etablissement des Mureaux (France). Espace and Defense.
SOFTWARE ENGINEERING METHODS IN THE HERMES ON-BOARD SOFTWARE
PHILIPPE LACAN and PAOLO COLANGELI *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 12 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

The HERMES On-board Software is executed in a complex multi-processor environment composed of two segregated computers pools. It provides all services to control the trajectory and the attitude of the space plane and its configuration. It also provides aids to the On-board Crew and the Ground Facilities in the Mission and Space Vehicle management. Being highly 'Safety Critical', the attitude control functions are foreseen to be supported by a quad-computers pool in hot redundancy, running in parallel and tightly synchronized. To support 'Mission Critical' functions, as mission and vehicle management, a dual-computers pool in cold redundancy is the baseline. This paper describes how the use of HOOD methodology has been experienced in the HERMES On-board Software Mock-Up framework, from now onwards designated for the sake of brevity as MU. In this technical survey of MU, a number of figures characterizing application size, specification and design complexity of the developed software along with a technical balance of the experienced methods are given. Derived from text

N94-29327# Thomson-CSF, Boulogne-Billancourt (France). CNI Div.
REACTIVE SYSTEM SOFTWARE CONCEPT WITH AUTOMATION USING THE LDS LANGUAGE [CONCEPTION LOGICIELLE DE SYSTEME REACTIF AVEC UNE METHODOLOGIE D'AUTOMATES UTILISANT LE LANGAGE LDS]
J. J. BOSC *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 7 p (SEE N94-29315 08-61) Nov. 1993 In FRENCH
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The phase of conception of a reactive system is the most important step, as the paths that are chosen will only be validated when the software is integrated with the material and when the real time conditions are tested and verified. Thus, a very strict method has to be adopted, which takes into account the specifics of the problems to be solved. The question is to assess how far the LDS language can be taken and what associated coding techniques can be used. Transl. by FLS

N94-29329# Alenia, Nerviano (Italy).
POTENTIAL SOFTWARE FAILURES METHODOLOGY ANALYSIS
M. NOGARINO, D. COPPOLA, and L. CONTRASTANO *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 7 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

Nerviano Plant is mainly involved in the development of complex avionic systems, of which software is essential component, often presenting safety critical features. The traditional techniques and methods imposed to support them with additional refinement tools to build the product safety during developing phases are inadequate. The paper describes a methodological approach for the systematic identification and classification of the effects caused by potential software failures. The potential software failures are identified evaluating the effects that would be produced by incorrect outputs on the other software parts and on the external environment. Furthermore, the proposed approach allows us to evaluate the necessity of introducing fault tolerance, recovery and backup procedures, and to define the adequate quantity and typology of testing and quality activities. Derived from text

N94-29330# Rome Lab., Griffiss AFB, NY.
ROME LABORATORY SOFTWARE ENGINEERING TECHNOLOGY PROGRAM
ELIZABETH S. KEAN *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 7 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

This paper highlights the technology recently developed or under development in the US Air Force's Rome Laboratory Software Engineering Technology Branch. This program is generic in nature and is focused around the development and support of large, mission critical and embedded software systems, and thus, is very relevant to the development and support of avionics systems. Further, when a technology is programming language sensitive or a demonstration vehicle requires selection of a specific language, the program language selected is always Ada. Finally, this program has four major thrusts. One thrust emphasizes system definition technology and is concerned with development and validation of requirements and specifications. A second thrust explores and builds technology for integrated software and system engineering environments, with emphasis on tools, process support and enforcement, and support to development and acquisition managers. New explorations in this area include certification methodologies and tools for reusable software components, and software fault-tolerance (robustness). A third thrust deals with the specification, prediction, and assessment of software quality. Rome Lab has a framework for dealing with all aspects of software quality that has proven itself in Japan. The newest thrust is on software engineering for high performance computing. This unique program is evaluating and developing generic software methods and tools for using high performance, massively parallel computers in embedded and other mission critical applications.
Derived from text

N94-29335# Alenia, Turin (Italy).
SOFTWARE TESTING PRACTICES AND THEIR EVOLUTION FOR THE 1990'S
PATRIZIA DICARLO *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 9 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The experiences of an aerospace company in solving specific problems associated with the host testing of embedded software is described. Operational applicability and exploitation of off-the-shelf tools, solutions for the management of both process and testing information, and the impact of the possible use of formal methods for the automatic generation of test cases are investigated and assessed from the user's point of view. The driving topics are the analysis of the effects of the assessed solutions on the current working practices together with their transfer to operational divisions. Author (revised)

N94-29337# Wright Lab., Wright-Patterson AFB, OH. Avionics Logistics Branch.
TESTING OPERATIONAL FLIGHT PROGRAMS (OFPS)
CHARLES P. SATTERTHWAITE *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 10 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The ability to accurately test a system is a highly desirable feature in the engineering design process. The ability to model your system's environment and to exercise your system, in that environment, is also highly desirable. Operational Flight Programs are the software programs of avionics embedded computer systems. Not only is it desirable to be able to test and model Operational Flight Programs, it is essential. The consequences of not performing accurate Operational Flight Program testing can be devastating. Some of these include premature weapons release, erroneous flight instrument displays, and complete system failure. In order to test Operational Flight Programs, there are several things one must know about the Operational Flight Program, its weapons system host, its support environment, and how to generate and perform its test. This paper will address these issues as it develops a strategy to test an Operational Flight Program.
Author (revised)

N94-29338# TA Consultancy Services Ltd., Farnham (England).
INTEGRATED FORMAL VERIFICATION AND VALIDATION OF SAFETY CRITICAL SOFTWARE
N. J. WARD *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 11 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

Embedded software providing the functionality for a flight vehicle self destruct system was judged to be safety critical and required the highest level of assurance in its correctness. In order to achieve this a program of independent verification and validation was initiated which involved the definition of a formal specification of the software combined with static analysis and dynamic testing. The formal specification, written in an Object Oriented form of Z, was used to clarify the requirements and to provide a definition against which the code could be formally verified. A range of static analyses were performed culminating in Compliance analysis which effectively provided a proof of the code against low level mathematical specifications that were refined down from the Z specification. The dynamic test sets were chosen partly from the requirements specification and partly from the static analysis results so that complete path coverage through every module was achieved. The work revealed a number of errors within the code and its specifications, which were corrected. Through its rigor and the identification of errors, the analysis has given a very high degree of confidence in the correctness of the software.
Author (revised)

N94-29339# Air Force Systems Command, Wright-Patterson AFB, OH.
A DISCIPLINED APPROACH TO SOFTWARE TEST AND EVALUATION
J. LEA GORDON *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 8 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

This paper discusses the impact DOD development standards and Integrated Product Teams have had on influencing F-22 cockpit Controls and Displays software test and evaluation. Author

N94-29340# Defence Research Agency, Portland (England). Sonar Signal and Data Processing Div.
THE UNICON APPROACH TO THROUGH-LIFE SUPPORT AND EVOLUTION OF SOFTWARE-INTENSIVE SYSTEMS
DONALD NAIRN *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 11 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

A new approach is presented to the through-life support and evolution of software-intensive systems. The new approach involves a sequence of development contractors. The problems addressed have to do with the avoidance of a 'through-life dependency' on any of the development contractors, and of achieving a unified engineering system description without imposing undue restrictions on the use of evolving software methodologies. The UNICON approach is to vest the through-life continuity in a unified engineering description held in a new type of Project Support Database. This scheme now views the development contractors as having a 'jobbing' role. The technical feasibility of this approach was held to depend on achieving a much more complete engineering description--from the Statement of Requirement, through to the mapping of the software onto the hardware (variants)--than any yet available. This led to the development of the UNICON system description language, based on extensions to the familiar ENTITY/RELATION/ATTRIBUTE notation. Details are presented of a reverse engineering experiment. Author (revised)

N94-29341# Electronic System G.m.b.H., Munich (Germany). Elektroniksystem- und Logistik.
A GENERALIZATION OF THE SOFTWARE ENGINEERING MATURITY MODEL
KARL G. BRAMMER and JAMES H. BRILL *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 9 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The software process consists of the methods, practices, and tools used to generate a software product. The Software Engineering Institute at Carnegie Mellon University has developed a capability maturity model (CMM) which defines five levels of maturity for the software process. Also included are sets of criteria that allow the specific assessment of actual software engineering maturity in given projects or organizations. In aerospace projects, software engineering very often is coupled with or embedded in systems engineering. It is therefore desirable to know if and how the CMM can be extended to systems engineering. The paper shows that this approach is feasible. After a brief summary of the original capability maturity model, an overview and comparison of software and systems engineering disciplines is provided. Differences between software and systems engineering are highlighted and modifications are proposed to adapt and generalize the CMM accordingly. Finally, the framework for a systems engineering maturity model is presented. This model is intended as a reference scale for systems engineering capability, in a similar way as the CMM applies to the software process. Author (revised)

N94-29343# Naval Air Warfare Center, Warminster, PA. Software and Computer Technology Div.
THE DISCIPLINE OF DEFINING THE SOFTWARE PRODUCT
JOHN K. BERGEY *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 13 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

An initiative was undertaken to establish a de facto project standard for a 'software product' for mission critical computer resources (MCCR). This effort is an outgrowth of a risk reduction approach to improving the MCCR software development and acquisition process based on Deming's quality principles. While defining a 'software product' might appear to be rudimentary, the hypothesis is put forth that the software product itself, which has been inexplicably neglected by the software engineering community, is the key element and focal point for understanding and improving the software development and acquisition process. A model of a 'software product' is described that was developed to promote uniform software product nomenclature, serve as a reference point for software process improvement, provide a basis for developing a more cost-effective software documentation standard, and provide a more rigorous means of specifying software deliverables for MCCR. Other potential benefits of the software product model include providing a convenient and effective means to uniformly baseline diverse software products, establish software configuration management and control, ensure the capture of all software components required for regeneration, provide a natural mechanism for the collection of software product metrics, and facilitate the on-line sharing and reuse of software programs, documents, and data. The software product model that has been developed is referred to as SPORE, which stands for software product organization and enumeration. SPORE is a graphical, hierarchical model that provides a complete and logical decomposition and description of a software product for MCCR. Author (revised)

N94-29344# British Aerospace Defence Ltd., Preston (England). Military Aircraft Div.
SDE'S FOR THE YEAR 2000 AND BEYOND: AN EF PERSPECTIVE
D. J. GOODWIN *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 8 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The process of selecting a software development environment for the embedded software of a large, complex military aircraft project can be long and costly. The process adopted on the European Fighter Aircraft (EFA) project by British Aerospace (BAe) is described, from the initial research and prototyping exercises performed in the seventies to the demonstration of the technology on the experimental aircraft project and finally leading to the collaboration with the Eurofighter partner companies (EPC's), building on European software experience to specify, procure, and release the EFA software development environment (EFA SDE). Issues arising within the EF forum that could influence the development of SDE's for future military aircraft projects are described. Author (revised)

N94-29345# Centre d'Etudes et de Recherches, Toulouse (France). Dept. d'Etudes et de Recherches en Informatique.
DISTRIBUTED APPLICATIONS AND FAILURE TOLERANCE PROGRAMS USING A RECONFIGURABLE PARALLEL ARCHITECTURE [UN ENVIRONNEMENT DE PROGRAMMATION D'APPLICATIONS DISTRIBUEES ET TOLERANTES AUX PANNES SUR UNE ARCHITECTURE PARALLELE RECONFIGURABLE]
CH. FRABOUL and P. SIRON *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 7 p (SEE N94-29315 08-61) Nov. 1993 In FRENCH
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

The studies conducted within the MODULOR project were centered on the necessary specifications for the creation of a modular parallel machine whose dynamics could be reconfigured. The software tools needed for reconfiguration during the development of parallel applications were also studied. The functional architectural reconfiguration was first considered, in view of automatically adapting the interconnective topology as efficiently as possible for a given application. Adding reconfiguration capabilities to the interconnective systems, in order to ensure a tolerance of the parallel architecture against processing systems failure, was treated in the second part of the study. The studies stress the importance of the complementary reconfiguring systems ('functional' and 'in case of failure') and define the architecture which guarantees the maximum efficiency in real time communications, in spite of the failure of some of the components of the system. Transl. by FLS

N94-29346# Alenia, Turin (Italy).
A COMMON APPROACH FOR AN AEROSPACE SOFTWARE ENVIRONMENT
F. D. CHERATZU *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 6 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

AIMS is a European industrial research project which focuses on the process for the development and maintenance of embedded computing systems which are an integral part of high technology aerospace products. It is a user driven project which uses a problem oriented approach to solve the difficulties encountered in the production of such systems. The relevance of the proposed solutions to the problems is ensured by involving aerospace engineers, who work on the development and maintenance of embedded systems. This involvement ensures that new technologies, or improved practices, can be rapidly introduced into operational projects. Author (revised)

N94-29347# Defence Research Agency, Farnborough, Hampshire (England). Flight Systems.
A DISTRIBUTED OBJECT-BASED ENVIRONMENT IN ADA
M. J. CORBIN, G. F. BUTLER, P. R. BIRKETT, and D. F. CRUSH *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 6 p (SEE N94-29315 08-61) Nov. 1993 Sponsored by Ministry of Defence
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

An object-based environment for implementing distributed systems is described. This can be used to create worlds of interacting objects, operating over a network of processors. The precise manner of the distribution is transparent to the objects within the environment. A prototype of this environment is being implemented in Ada, augmented by support for object-oriented constructs. This is intended for use in real-time simulations of combat missions and will be known as Multi-sim. Author

N94-29349# Entreprise 2 Software, Saint-Cloud (France).
ENTREPRISE 2: A PCTE INTEGRATED PROJECT SUPPORT ENVIRONMENT
GERARD OLIVIER *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 9 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

Entreprise 2 users are in the technical and scientific software industry and include members of software development and maintenance teams at all levels: administrators, project managers, project leaders, those in charge of subprojects or tasks, developers, and maintenance staff. Entreprise 2 is also designed for software tool editors, who need an integrated CASE tools environment in which they can develop and distribute their own tools. Developers of software systems face numerous problems directly related to software development, upkeep, and maintenance. Entreprise 2 provides a solution to these problems, at both organizational and technical levels. Derived from text

N94-30513# Royal Military Academy, Brussels (Belgium). Electrical Engineering Dept.
KNOWLEDGE COMBINATION AND DATA FUSION WITH APPLICATION TO RECOGNITION SYSTEMS
CHRISTIAAN PERNEEL, MICHEL DEMATHELIN, and MARC ACHEROY *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 10 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

The fuzzy logic theory is used to derive knowledge combination rules for heuristic search algorithms and data fusion problems. Heuristic search algorithms are especially designed for expert systems which have to explore a large solution space in a limited amount of time. Therefore, search algorithms using heuristic knowledge are designed to limit the exploration of the solution space while preserving some quality in the results. An automatic target recognition expert system was designed using this approach. However, the fuzzy logic approach could be applied to other types of expert systems and to data fusion problems. Author (revised)

N94-36626# Thomson-CSF, Bagneux (France). Div. Systemes Electronique.
HIGH ACCURACY CONTROL ALGORITHM APPLICATION TO A TRACKING TURRET
P. NICODEME and P. POULAIN *In* AGARD, Pointing and Tracking Systems 11 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A03/MF A02

The aim of the application described in this paper is to provide high accuracy control to a servomotor driven tracking turret. The system principles and requirements (target tracking and pointing capabilities for static and dynamic working) are presented. Then, the functional structure of the servos system to be controlled is explained: (1) mechanical system; (2) motor and electronics; and (3) digital computer for servo loops. The steps of the study to obtain robust, 'modern' and accurate control laws are detailed: (1) mechanical modelization for computer simulation; (2) motor and electronic representation; (3) simplified linear transfers identification (methods to obtain linear transfer; results for this particular application); and (4) design of high capability controllers. For this servo application, two 'new control methods' are presented for various hardware configuration of the turret (with or without a mechanical structure damping system such as a tachometer loop): (1) 'Model Based Predictive Control' with the 'Predictive Functional Control' method and the associated computer aided design tool; and (2) H-infinity controllers and the CAD tool. The basic principles of the two methods are explained and the way to obtain control laws are presented. Then, some simulation results obtained with these control laws for various pointing scenarios are discussed: (1) fixed or low speed target; (2) dynamic capability (gathering from an initial position to the turret, high speed passing target); and (3) stability and robustness (disturbance robustness, mechanical characteristic variation). The constraints and advantages of the various control laws are compared and discussed. Then, some trial results are summarized in a brief description. As a conclusion of the paper, the compliance of the results obtained by these methods with high accuracy requirements for pointing and tracking systems is discussed. Author (revised)

N94-37279# SR Research, Toronto (Ontario).
LOW COST SOFTWARE-BASED RENDERING AND STEREOSCOPIC INTERFACES FOR TELEOPERATION AND VIRTUAL REALITY
DAVE M. STAMPE and JULIUS J. GRODSKI *In* AGARD, Virtual Interfaces: Research and Applications 6 p (SEE N94-37261 12-53) May 1994
(AGARD-CP-541) Copyright Avail: CASI HC A02/MF A02

Many interface systems require generation of 3D graphics, whether as the entire display in virtual reality systems or as an overlay on live video in teleoperation. Costs must be kept low to make such systems practical, but real-time response speed must not be sacrificed. Described here is a very low-cost rendering and VR support package for 386 and 486 PC's, which requires no added hardware to achieve real-time drawing rates (20 to 60 frames per second). It includes integral support for generation and display of stereoscopic graphics in many formats, including field-alternate displays using LCD shutter glasses, and wide-angle head mounted displays. Many common PC interface devices are supported, including mouse, joystick, 6D pointing devices, and head trackers. Inexpensive PC multimedia cards allow output to be recorded on a VCR, or overlaid onto live video, including stereoscopic TV images from teleoperated remote cameras. Full source code is available, allowing the software to be customized for any application. Author

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COMPUTER SYSTEMS

Includes computer networks and special application computer systems.

N94-29333# National Research Council of Canada, Ottawa (Ontario). Software Engineering Lab.
DESIGN OF A THINWIRE REAL-TIME MULTIPROCESSOR OPERATING SYSTEM
CHARLES GAUTHIER *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 11 p (SEE N94-29315 08-61) Nov. 1993
(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

As more and more capabilities are added to avionics and other real-time or embedded systems, it becomes necessary to increase the processing power of the underlying executors. At any point, technology imposes limits on the available performance of individual processors. Increasing the computing power beyond those limits requires the use of multiple processors. This paper presents an implementation of a multiprocessor multitasking real-time operating system on difficult architectures. The development of applications on this operating system does not require any special software development tools such as special compilers. Furthermore, the applications can be ported to a very wide range of multiprocessor architectures. The principles of operation of the operating system can be applied to the implementation of an Ada runtime environment, if some restrictions are observed. Author (revised)

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CYBERNETICS

Includes feedback and control theory, artificial intelligence, robotics and expert systems.

N92-32442# Naval Weapons Center, China Lake, CA. Attack Weapons Dept.
TARGET CUING: A HETEROGENEOUS NEURAL NETWORK APPROACH
HOWARD MCCAULEY *In* AGARD, Integrated Target Acquisition and Fire Control Systems 4 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A01/MF A02; 1 functional color page

Autonomous analysis of complex image data is a critical technology in today's world of expanding automation. The growth of this critical field is slowed by problems in traditional image analysis methods. Traditional methods lack the speed, generality, and robustness that many modern image analysis problems require. While neural networks promise to improve traditional techniques, homogeneous neural network systems have difficulty performing all the diverse analysis required of an autonomous system. Proposed here is a dual-staged, heterogeneous neural network approach to image analysis; specifically, a way to solve the cuing problem. Author

N93-13238# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
MACHINE PERCEPTION [LA PERCEPTION DE L'ENVIRONNEMENT PAR SENSEURS AUTOMATIQUES]
Aug. 1992 205 p Lecture series held in Hamton, VA, 3-4 Sep. 1992, in Neubiberg, Germany, 14-15 Sep. 1992, and in Madrid, Spain, 17-18 Sep. 1992
(AGARD-LS-185; ISBN-92-835-0684-7) Copyright Avail: CASI HC A10/MF A03

Human perceptual capabilities involve the extraction of task-oriented information from environmental stimuli through physical sensing and the use of background knowledge. There are many activities underway aimed at providing similar capabilities of artificial machine perception. Some success is achieved by exploiting what is known of corresponding human cognitive processes and by making use of the increasing power of information processing techniques. For this purpose, the recognition of sharply contrasted as well as fuzzy patterns (stationary or dynamically changing) plays an important role along with other aspects of processing of complex information structures. This lecture series covers the following subjects: pattern recognition techniques; real time visual machine perception, principles and applications in guidance and control (G&C); and real time speech recognition and understanding in the G&C domain. For individual titles, see N93-13239 through N93-13245.

N93-13239# Daimler-Benz A.G., Ulm (Germany). Inst. for Information Technology.
PERCEPTION-BASED AND MACHINE-ORIENTED SIGNAL PROCESSING WITHIN SPEECH UNDERSTANDING SYSTEMS
HELMUT MANGOLD *In* AGARD, Machine Perception 16 p (SEE N93-13238 03-63) Aug. 1992
(AGARD-LS-185) Copyright Avail: CASI HC A03/MF A03

Automatic recognition and understanding of speech signals is one of the key issues of advanced information technology. Language and speech are the relevant topics of cognition and therefore to understand spoken and written language offers basic capabilities for universal processing of information. Speech is man's generic communication medium. Information transfer is widely done by speech communication between humans. There is a basic commonality of understanding each other's spoken messages. This common understanding must be the basis of machine understanding too. Automatic recognition and understanding of spoken language is done in a multistep approach, which starts with the low level signal processing. The output of the recognition step is word recognition. Many possible words, the so called word hypotheses are the basis for intensive linguistic processing. Linguistic processing includes syntactic analysis and semantic analysis. The semantic analysis needs, again, many additional parameters from spoken language, like intonation and prosody to derive the meaning of a spoken phrase. All the processing of natural speech is narrowly related to human information processing. It is therefore possible to learn much from our human processing or from models of this processing. On the other side, statistical methods of information processing offer rather systematic and in many cases advanced methods for handling much of the information contained in speech using purely statistical approaches. To estimate the advantages of the more statistical approaches or more rule based approaches will be a great challenge for future research. Human perception will always be a guide for how to process speech with machines. Author

N93-13240# Carnegie-Mellon Univ., Pittsburgh, PA. School of Computer Science.
SENSING AND INTERPRETATION OF 3-D SHAPE AND MOTION
TAKEO KANADE *In* AGARD, Machine Perception 36 p (SEE N93-13238 03-63) Aug. 1992
(AGARD-LS-185) Copyright Avail: CASI HC A03/MF A03

Robotics is where artificial intelligence meets the physical world. Computer vision provides robots with the perceptual capabilities which are especially critical for robots that operate in an unconstrained natural environment. In computer vision, recovery of 3D shape and motion is the key to understanding scenes. Thus, the problem has attracted much of the attention of vision researchers over the last decade, and many sophisticated algorithms have been developed. I address three recently developed methods for sensing and interpreting 3D shape and motion: the factorization method for image sequence analysis; very fast range imaging by analog VLSI smart chip; and the multi-baseline stereo method. It is interesting to note that while the performance of these methods has exceeded that of previous methods, the algorithms, themselves are simpler and more straightforward. In addition to enhanced performance, these algorithms are suitable for real-time parallel implementation by special hardware or VLSI. A detailed description of these methods is presented. Author

N93-13241# SRI International Corp., Menlo Park, CA. Artificial Intelligence Center.
BUILDING AND USING SCENE REPRESENTATIONS IN IMAGE UNDERSTANDING
H. HARLYN BAKER *In* AGARD, Machine Perception 12 p (SEE N93-13238 03-63) Aug. 1992 Sponsored in part by Fujitsu System Integration Lab.
(Contract(s)/Grant(s): DACA76-85-C-0004; DACA76-90-C-0021; DACA76-92-C-0003)
(AGARD-LS-185) Copyright Avail: CASI HC A03/MF A03
The task of having computers able to understand their environments through direct imaging has proved to be formidable. With its beginnings about 30 years ago, the field of computer vision has grown as a major part of the pursuit for artificial intelligence. Most elements of this pursuit - language understanding, reasoning and planning, speech - are very difficult challenges, but vision, with its high dimensionality of space, time, scale, color, dynamics, and so forth, may be the most challenging. Early attempts to develop computer vision focused on restricted situations in which it was feasible to provide the computer with fairly complete descriptions of what it would encounter. In such cases, single images provided the sensory information for analysis. As the domains of application grew, the requirements for more competent descriptions of the world increased. Dealing with three-dimensional (3D) dynamic structures (the real world) from 3D dynamic platforms (we humans) calls for greater capabilities on both the analysis and synthesis sides of the issue. The analysis side is the processing of sensory data for such tasks as recognition and navigation, and a number of techniques are discussed here for dealing with these two-, three-, and higher-dimensional data. The synthesis side is the construction of 'internal' descriptions of what is seen in the environment - constructed now so that they may be used subsequently for the above tasks. This latter issue is the underlying theme we pose in this paper - developing representations from vision that will later enable effective automated operations in our 3D dynamic environments. Author

N93-13242# Paris-Sud Univ., Orsay (France). Inst. d'Electronique Fondamentale.
SILICON VISION: ELEMENTARY FUNCTIONS TO BE IMPLEMENTED ON ELECTRONIC RETINAS
B. ZAVIDOVIQUE and T. BERNARD *In* AGARD, Machine Perception 17 p (SEE N93-13238 03-63) Aug. 1992
(AGARD-LS-185) Copyright Avail: CASI HC A03/MF A03
A smart retina is a device which intimately associates an optoelectronic layer with processing facilities. The rapprochement between acquisition and processing is particularly suited for the emergence of novel kinds of interaction, between analog and digital massive computations. Therefore, several attempts of analog, possibly neural, computations linked to the vision process are listed and discussed. But analog is not enough for really smartening retinas. Then, an additional plausible coat of cellular boolean iterative processing in these 'human size' vision machines is described, and commented on through examples. Author

N93-13243# Elettronica San Giorgio S.p.A., Genoa (Italy). Research and Development Dept.
3-D COMPUTER VISION FOR NAVIGATION/CONTROL OF MOBILE ROBOTS
G. B. GARIBOTTO and S. MASCIANGELO *In* AGARD, Machine Perception 13 p (SEE N93-13238 03-63) Aug. 1992
(Contract(s)/Grant(s): ESPRIT PROJ. P-940; ESPRIT PROJ. P-2502)
(AGARD-LS-185) Copyright Avail: CASI HC A03/MF A03
The aim of this lecture is to investigate how much visual sensors may be effective in supporting autonomous navigation of mobile robots. Although in practical realizations, with robustness and reliability constraints, it is always necessary to integrate multi-sensor modalities, the discussion here is limited to an analysis of computer vision advantages and disadvantages, with particular attention given to: (1) a binocular stereo vision module for obstacle detection, with no precise calibration (reactive process to operate at a fast rate, from 5 to 10 Hz); trinocular stereovision based on segment primitives for the reconstruction of free space for navigation, in which case an acccurate calibration procedure is requested; and landmark detection for self-positioning and orientation of a mobile vehicle, using perspective invariants, for indoor navigation. Some comments are also provided on computer vision architectures to support real time implementations. A real-time front end vision subsystem is described, which is able to compute 3D segment based stereovision at 5 Hz and segment token tracking at 10 Hz. Finally, some demo arrangements are briefly discussed where an intense experimentation of such results is in progress, as a test bed for different industrial applications. Author

N93-13244# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany). Dept. of Aerospace Technology.
MACHINE PERCEPTION EXPLOITING HIGH-LEVEL SPATIO-TEMPORAL MODELS
E. D. DICKMANNS *In* AGARD, Machine Perception 17 p (SEE N93-13238 03-63) Aug. 1992
(AGARD-LS-185) Copyright Avail: CASI HC A03/MF A03
A paradigm for machine perception is presented which takes time and 3D space in an integrated manner as the underlying framework for internal representation of the sensorially observed outside world. This world is considered to consist of material and mental processes evolving over time. The concept of state and control variables developed in the natural sciences and engineering over the last three centuries is exploited to find a new, more natural access to dynamic real-time vision and intelligence. Schopenhauer's conjecture of 'The world as evolving process and internal representation' (1819) is combined with modern recursive estimation techniques (Kalman 60) and some components from geometry and AI in order to arrive at a very efficient scheme for autonomous robotic agents dealing with evolving processes in the real world in real time. Application to autonomous mobile robots is discussed. Author

N93-13245# Roke Manor Research Ltd., Romsey (England).
THE 3-D COMPUTER VISION TECHNIQUES FOR OBJECT FOLLOWING AND OBSTACLE AVOIDANCE
RICHARD EVANS *In* AGARD, Machine Perception 24 p (SEE N93-13238 03-63) Aug. 1992 Sponsored in part by Commission of the European Communities
(AGARD-LS-185) Copyright Avail: CASI HC A03/MF A03
Imaging sensors are powerful tools enabling remote control, by tele-operation, of numerous tasks where the operator requires an appreciation of the three-dimensional structure of the viewed scene. Passive video sensors also lend themselves to tasks where covert operation or electromagnetic compatibility is required. A commonly mooted tele-operational task is that of driving a known vehicle through an unknown terrain - or keeping station on a known object moving through an unknown terrain. The computer vision aspects of automating this task are divided into two separate vision functions, which are the subjects of this paper: (1) analysis of image sequences of a general scene to extract its three dimensional (3D) structure without any prior information; and (2) analysis of images of a well defined object, to extract its 3D position and orientation relative to the sensor. For both these functions, the paper provides a brief introduction to possible techniques followed by further descriptions of particular systems, DROID and RAPiD, developed by Roke Manor Research Limited. DROID is a general, feature-based 3D vision system using the structure-from-motion principle. That is, it uses the apparent image-plane movement of localized features viewed by a moving sensor to extract the three-dimensional structure of the scene. RAPiD is a model-based real-time tracker which extracts the position (X,Y,Z) and orientation (roll, pitch, yaw) of a known object from image data. The system operates iteratively, using prediction of object pose (position and orientation) to cue the search for selected edge features in subsequent imagery. This approach results in minimal processing of image pixels, so that the system can be implemented at full video rate using modest hardware. Author

N93-22023# Naval Air Warfare Center, China Lake, CA. Weapons Div.
THE MISSLE-BORNE INTEGRATED NETWORK DEMONSTRATION PROGRAM
M. L. MUMFORD, D. K. ANDES, and L. L. KERN *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 8 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A02/MF A02
The Missile-Borne Integrated Neural Network Demonstration (MINND) Program is a Navy 6.3A Advanced Technology

Demonstration program, with the goal of demonstrating the application of artificial neural network technology to improving the performance of IR seekers. The specific technical objective is to demonstrate the realtime detection of moving point targets in IR clutter. The program has developed neural network-based system design in several stages of increasing capability for moving target detection. The program has developed several stages of hardware, supporting neural chip testing/learning, followed by realtime processing hardware for implementation of software designs. MINND is currently in its final phase of integrated demonstration testing using real sensor inputs. Author

N94-18241# Air Force Inst. of Tech., Wright-Patterson AFB, OH.

INTRODUCTION TO QUANTITATIVE FEEDBACK THEORY (QFT) TECHNIQUE

CONSTANTINE H. HOUPIS *In* AGARD, Non Linear Dynamics and Chaos 20 p (SEE N94-18236 04-77) Jun. 1993

(AGARD-LS-191) Copyright Avail: CASI HC A03/MF A02

Quantitative Feedback Theory (QFT) has achieved the status as a powerful design technique for the achievement of assigned performance tolerances over specified ranges of plant parameter uncertainties without and with control effector failures. It is a frequency domain design technique utilizing the Nichols chart (NC) to achieve a desired robust design over the specified region of plant parameter uncertainty. An introduction to QFT analog and discrete design techniques is presented for both multiple-input single-output (MISO) and multiple-input multiple-output (MIMO) control systems. QFT computer aided design (CAD) packages are readily available to expedite the design process. The purposes of these lectures are: (1) to provide a basic understanding of QFT, (2) to provide the minimum amount of mathematics necessary to achieve this understanding, (3) to discuss the basic design steps, and (4) to present two practical examples. Author (revised)

N94-29328# Rome Lab., Griffiss AFB, NY. Knowledge Engineering Branch.

ARTIFICIAL INTELLIGENCE TECHNOLOGY PROGRAM AT ROME LABORATORY

ROBERT N. RUBERTI and LOUIS J. HOEBEL *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 11 p (SEE N94-29315 08-61) Nov. 1993

(AGARD-CP-545) Copyright Avail: CASI HC A03/MF A03

This paper provides an overview of the Artificial Intelligence (AI) Program at Rome Laboratory. The three major thrusts of the program are described. The Knowledge-Based Planning Program seeks to develop the next generation of AI planning and scheduling tools. The engineering of knowledge-based systems focuses on the development and demonstration of technology to support large-scale, real-time systems of knowledge-based components. The knowledge-based software assistant program seeks to develop a new programming paradigm in which the full life-cycle of software activities are machine mediated. Author (revised)

N94-36628# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany). Fakultaet fuer Luft-und Raumfahrttechnik.

TWO-AXIS CAMERA PLATFORM FOR MACHINE VISION

J. SCHIEHLEN and E. D. DICKMANNS *In* AGARD, Pointing and Tracking Systems 6 p (SEE N94-36616 12-18) May 1994

(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02

Mobile robots operating autonomously have to perceive their environment; many advantages favor using a vision sensor. The concept of dynamic vision is an adequate solution to this problem. The ability to track moving objects is essential. Therefore, a two axis camera platform is described having several modes of operation, which can be mounted on a mobile robot. An active vision system is presented, including the design of the pan-tilt head and the controller. Problems arising due to image processing delays, robots' own motion and platform actuator disturbances, e.g. friction, are treated. An aircraft application for vision based autonomous landing is given. Author

N95-14942# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

ADVANCED GUIDANCE AND CONTROL ASPECTS IN ROBOTICS [LA PERCEPTION DE L'ENVIRONNEMENT PAR SENSEURS AUTOMATIQUES]

Jun. 1994 227 p Lecture series held in Lisbon, Portugal, 6-7 Jun. 1994, in Athens, Greece, 9-10 Jun. 1994, and in Ontario, 21-22 Jun. 1994

(AGARD-LS-193; ISBN-92-835-0751-7) Copyright Avail: CASI HC A11/MF A03

To ensure the capability of defense, a demand for equipment and systems which can be embraced under the title of 'Robotics' will emerge in the near future. In this context, 'Robotics' represents a specific problem area involving all the guidance and control functions which are associated with achieving goal-oriented autonomous behavior in structured and unstructured environments for mobile and manipulator systems as applied to ground, sea, air, and space operations. Related robotic systems must combine constituent functions such as intelligent decision making, control, manipulation, motion, sensing, and communication. The scope of the special course will cover new developments in the areas of autonomous navigation for planetary and surface systems, and control and operations of remote manipulators. For individual titles, see N95-14943 through N95-14949.

N95-14943*# National Aeronautics and Space Administration, Washington, DC.

ROBOTICS TECHNOLOGY DEVELOPMENTS IN THE UNITED STATES SPACE TELEROBOTICS PROGRAM

DAVID LAVERY *In* AGARD, Advanced Guidance and Control Aspects in Robotics 21 p (SEE N95-14942 03-63) Jun. 1994

(AGARD-LS-193) Copyright Avail: CASI HC A03/MF A03

In the same way that the launch of Yuri Gagarin in April 1961 announced the beginning of human space flight, last year's flight of the German ROTEX robot flight experiment is heralding the start of a new era of space robotics. After a gap of twelve years since the introduction of a new capability in space remote manipulation, ROTEX is the first of at least ten new robotic systems and experiments which will fly before the year 2000. As a result of redefining the development approach for space robotic systems, and capitalizing on opportunities associated with the assembly and maintenance of the space station, the space robotics community is preparing a whole new generation of operational robotic capabilities. Expanding on the capabilities of earlier manipulation systems such as the Viking and Surveyor soil scoops, the Russian Lunakhods, and the Shuttle Remote Manipulator System (RMS), these new space robots will augment astronaut on-orbit capabilities and extend virtual human presence to lunar and planetary surfaces. Author

N95-14944# CompEngServ Ltd., Ottawa (Ontario).

MACHINE INTELLIGENCE: THE KEY TO GUIDANCE AND CONTROL IN ROBOTICS

B. ARCHIE BOWEN and DAVID G. BOWEN *In* AGARD, Advanced Guidance and Control Aspects in Robotics 43 p (SEE N95-14942 03-63) Jun. 1994

(AGARD-LS-193) Copyright Avail: CASI HC A03/MF A03

A robotics system is composed of a hardware platform which provides the stability, mobility, and manual dexterity and a software system which acts to interpret the input sensor data and the mission statement and then to create the required excitation to the hardware. Stated in this rather simplistic way, there seems to be little reason for the vast array of laboratories feverishly working on the creation of fully autonomous robots. The overall task and its components, however, has proven of intricate complexity, with succeeding layers of hidden problems becoming exposed just as a solution appears imminent. This paper is concerned only with the software components of a robotics system, and in particular with that portion of the system which comes under the general description of intelligent software. It is a 'stand-off' approach derived from a software engineer's point of view. The intent is to review, from a particular and perhaps novel point of view, the various software paradigms and their intrinsic capabilities and functionalities. This review provides the basis for a detailed map of the current capabilities of software paradigms onto the guidance and control problems of intelligent robotics systems. The paper is partitioned into two parts: Machine Intelligence as a Robotics

Component, and Expectations and Projections. In the first, a perspective of intelligent software is presented which provides the basis for considering guidance and control problems. In the second part, the utility of this perspective is demonstrated by exploring a generic guidance and control architecture. The paper ends by suggesting some approaches for future directions in developments in this field. Author

N95-14945# Martin Marietta Corp., Denver, CO. Astronautics Div.
CONTROL OF REMOTELY OPERATED MANIPULATION SYSTEMS
PAUL L. SHATTUCK *In* AGARD, Advanced Guidance and Control Aspects in Robotics 25 p (SEE N95-14942 03-63) Jun. 1994
(AGARD-LS-193) Copyright Avail: CASI HC A03/MF A03

Robotics systems are beginning to emerge as an effective alternative to humans for tasks that are either hazardous or routine and repetitive. Remotely operated manipulation systems have been accepted and widely used for the past ten to twenty years in two terrestrial applications: underwater exploration, servicing, and repair and handling of hazardous materials in the nuclear industry. Technology advances have enabled new, broad space and terrestrial applications for remotely operated manipulation systems. However, in order to promulgate robotic systems further in the terrestrial work place, elements of these systems must have requirements traceable to operations with humans nearby, or manipulation of delicate objects. A representative space-system manipulator will be used to provide an illustrative example of the evolution of remotely operated manipulation systems. The manipulator is initially intended to provide the astronauts a tool to perform routine tasks such as inspection, worksite preparation/teardown, or routine servicing and maintenance, thereby improving the astronauts' efficiency during EVA's. Emphasis is placed on the system-level requirements and design drivers. Technology advances that enable new applications, and impediments to using robotics, will also be discussed. Control techniques and the operator interface developed for this manipulator could be commercially demonstrated in an underwater servicing exercise - providing the link to the remotely operated manipulation system that are the subject of this lecture. Author

N95-14946# Canadian Space Agency, Saint Hubert (Quebec). Space Station Program.
CONTROL AND OPERATION OF SPACE MANIPULATOR SYSTEMS
CAMERON P. TRUDEL, D. G. HUNTER, and M. E. STIEBER *In* AGARD, Advanced Guidance and Control Aspects in Robotics 19 p (SEE N95-14942 03-63) Jun. 1994
(AGARD-LS-193) Copyright Avail: CASI HC A03/MF A03

As manned space flight passes into its fourth decade, many of the activities in space appear to be almost routine. However, the space environment is exceedingly hostile to humans and necessitates substantial effort and funding to provide an infrastructure to support human life. Increased attention is therefore being directed toward the application of robotics technology to more effectively carry out tasks in space which, up to now, have been carried out by human extravehicular activity (EVA), or which could not be carried out because of human limitations or limitations of available equipment. Manipulator systems are better suited to operation in the external space environment and can augment or replace the human presence. They can also play an important role in the spacecraft intravehicular activity (IVA) to replace some of the human tasks. To date few robots have been developed for space applications; however, as human activity increases in earth orbit and beyond, robotic systems will play an increasingly vital role. Control and operation of space manipulator systems are addressed with emphasis on those designed for the external space environment. Applications of the technology are discussed in the context of the Mobile Servicing System (MSS) being developed for the International Space Station. The Mobile Servicing System incorporates two manipulator systems, the Space Station Remote Manipulator System (SSRMS) and the Special Purpose Dexterous Manipulator (SPDM). The modes of operation and selectable control features are discussed with some of the more advanced features demonstrated by simulation and laboratory test results. Author

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NUMERICAL ANALYSIS

Includes iteration, difference equations, and numerical approximation.

N93-21522# Vrije Univ., Brussels (Belgium). Analyse van Strukturen.
NUMERICAL FINITE ELEMENT ANALYSIS OF DAMAGE USING MONTE CARLO TECHNIQUES
G. VANVINCKENROY and W. P. DEWILDE *In* AGARD, Debonding/Delamination of Composites 6 p (SEE N93-21507 07-24) Dec. 1992 Sponsored by Ministry of Economic Affairs; Science Policy Dept. and Belgian National Foundation for Scientific Research
(AGARD-CP-530) Copyright Avail: CASI HC A02/MF A03

A method, based on the finite element technique, is proposed in order to study the behavior of an adhesive single lap joint, together with stochastic material properties, taking into account the uncertainties of design parameters. The technique is applicable to linear and nonlinear problems, with more or less complicated structures. The needs are experimental determination of the components properties and numerical tools. Author (revised)

65

STATISTICS AND PROBABILITY

Includes data sampling and smoothing; Monte Carlo method; and stochastic processes.

N94-37327# Pratt and Whitney Aircraft, West Palm Beach, FL.
STATISTICAL CHARACTERIZATION OF RARE EVENTS
CHARLES ANNIS and SHARON VUKELICH *In* AGARD, Impact of Materials Defects on Engine Structures Integrity 10 p (SEE N94-37321 12-38) Apr. 1993
(AGARD-R-790) Copyright Avail: CASI HC A02/MF A02

Inexpensive computing power has made computer-intensive methods, such as Monte Carlo simulation, available to a wide range of engineering problems, including risk assessments for structural components. Because well-designed structures have low probabilities of failure during their service lifetimes, it has become increasingly helpful to simulate the behavior of these unlikely events, so as to quantify the risk of failure. This paper considers the behavior of the 'tails' of the statistical distributions chosen to describe the behavior of life-controlling variables and their influence on the estimation of aggregate risk. It may seem obvious that the form of the probability distributions will necessarily have a profound influence on the resulting estimated probabilities of failure. What is perhaps less obvious are the subtle differences among candidate distributions in the range where most defining data will necessarily be obtained, namely between their fifth and ninety-fifth percentiles. We examine and compare several commonly used distributions: normal, log-normal 2- and 3-parameter Weibull, and Beta. Also considered here is the often used, but less often understood, concept of confidence associated with a probability of failure. Because it relies on knowing which one of several potential underlying probability distributions actually governs the observed behavior, it can result in a meaningless estimate of 'confidence', and thus presents the potential for a false sense of security.
Author

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SYSTEMS ANALYSIS

Includes mathematical modeling; network analysis; and operations research.

N92-27888# Royal Air Force, London (England). Combat Operations Centre.
INTERDICTION MISSION PLANNING AND CO-ORDINATION DURING THE GULF CONFLICT 17 JANUARY - 27 FEBRUARY 1991
V. A. MEE and P. J. GOODMAN *In* AGARD, Air Vehicle Mission Control and Management 5 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A01/MF A03

The Gulf Air War started for Royal Air Force Tornado GR1 aircraft with the delivery of JP 233 weapons from low level at night. After sustaining unacceptable losses at low level, tactics changed to delivery of freefall 1000 lb bombs from medium level, at first by night and then by day. Accuracies, however, improved dramatically with the arrival in theatre of precision guided munitions. Described here is a typical mission covering all aspects from initial tasking by ATO, through mission planning and coordination with intelligence input to deconfliction and mission execution. Missions were flown as co-ordinated packages, Tornado GR1's being supported by F15C fighter escorts with EW support from F4G 'Wild Weasels' and EF111 'Raven' aircraft. Mission planning by the Royal Air Force was manpower intensive and could have been streamlined with the availability of more automated systems. Several lessons were learned from the conflict, which are listed and discussed. Author

N92-27889# Physics and Electronics Lab. TNO, The Hague (Netherlands).
AIRPOWER PLANNING AND BATTLE MANAGEMENT TRAINING AT AIRBASE LEVEL
P. SCHULEIN and R. F. W. M. WILLEMS *In* AGARD, Air Vehicle Mission Control and Management 9 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A02/MF A03

Airborne or Ground-Based Pilot Mission Planning is a single important link in the chain of activities that is required to facilitate operating airpower from an airbase. Other elements of that chain include Target Recce and Allocation and Sortie Generation. It turns out that information management problems associated with intelligence generation, also apply to effectively controlling Sortie Generation, both to make most efficient use of scarce resources and to generate an organization that is able to benefit from Pilot Mission Planning improvements. An obvious solution to improving an information management problem is designing a Command, Control Communications and Information System (C3IS). To improve design and development of these C3I systems, it is proposed to combine the design of those systems and the use of Battle Management Training Systems. Developing operational and training systems together has possibilities to increase user involvement and acceptance and incorporate studies towards not only just fielding a C3I system, but looking at the most effective combination of System and Organization. As a case, the design of the Airbase Operations Wargame for the Royal Netherlands Airforce is presented and some conclusions are drawn regarding the possible use of this system in designing C3I systems such as the Airbase Command and Control Information System ABCCIS. Author

N92-27891# Thomson-CSF, Bagneux (France).
AIR SITUATION ESTABLISHMENT IN A MOBILE MULTISENSOR ENVIRONMENT
C. RIVIERRE and M. DESBOIS *In* AGARD, Air Vehicle Mission Control and Management 5 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A01/MF A03

The impact of the mobility concept on an air command and control system is discussed. The subject is limited to the air picture establishment. Various aspects linked with mobility are pointed out as well as solutions to handle the additional difficulty at the data fusion level. These solutions are based on an original experience, on experiment results, and on study work. Advanced system capabilities which make more intensive use of airborne platforms, are also discussed. Author

N92-27892*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SITUATION ASSESSMENT IN THE PALADIN TACTICAL DECISION GENERATION SYSTEM
JOHN W. MCMANUS (Lockheed Aircraft Corp., Hampton, VA.), ALAN R. CHAPPELL (Lockheed Engineering and Sciences Co., Hampton, VA.), and P. DOUGLAS ARBUCKLE *In* AGARD, Air Vehicle Mission Control and Management 16 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

Paladin is a real-time tactical decision generator for air combat engagements. Paladin uses specialized knowledge-based systems and other Artificial Intelligence (AI) programming techniques to address the modern air combat environment and agile aircraft in a clear and concise manner. Paladin is designed to provide insight into both the tactical benefits and the costs of enhanced agility. The system was developed using the Lisp programming language on a specialized AI workstation. Paladin utilizes a set of air combat rules, an active throttle controller, and a situation assessment module that have been implemented as a set of highly specialized knowledge-based systems. The situation assessment module was developed to determine the tactical mode of operation (aggressive, defensive, neutral, evasive, or disengagement) used by Paladin at each decision point in the air combat engagement. Paladin uses the situation assessment module; the situationally dependent modes of operation to more accurately represent the complex decision-making process of human pilots. This allows Paladin to adapt its tactics to the current situation and improves system performance. Discussed here are the details of Paladin's situation assessment and modes of operation. The results of simulation testing showing the error introduced into the situation assessment module due to estimation errors in positional and geometric data for the opponent aircraft are presented. Implementation issues for real-time performance are discussed and several solutions are presented, including Paladin's use of an inference engine designed for real-time execution. Author

N92-27893# Royal Aerospace Establishment, Farnborough (England).
A TEAMWORK MODEL OF PILOT AIDING: PSYCHOLOGICAL PRINCIPLES FOR MISSION MANAGEMENT SYSTEMS DESIGN
R. M. TAYLOR and S. J. SELCON *In* AGARD, Air Vehicle Mission Control and Management 14 p (SEE N92-27887 18-01) Mar. 1992
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

Advances in automation and control/display technology have enabled design effort to focus on how aircrew system interfaces can be created to help perform the mission and to help solve mission problems. Evidence of this development towards a concept of aiding the pilot, rather than replacing pilot functions, comes from recent systems proposed for both ground and airborne mission control and management. Interface design solutions for aircrew systems problems usually evolve pragmatically, based on considerations of convenience, availability, utility, familiarity and operator acceptance. Currently, there is no substantial theory of the pilot-aiding concept. In the absence of a theoretical basis, pilot-aiding interfaces for mission control and management will lack theoretical consistency and they will be without any formal, systematic procedures for establishing design criteria, goals and objectives. Some of the consequences of this will be sub-optimal utilization of system function, loss of situational awareness, a low level of pilot trust, and failure to reduce pilot workload. In order to address the requirements for a theory of the pilot-aiding concept, we propose a model based on the principles of teamwork, where the human and 'electronic' crew components work co-operatively towards achieving mission objectives. Characteristics of the model are incorporated into a prototype tool for auditing the quality of interface design solutions with respect to teamwork criteria. Teamwork audits are reported for several aircrew systems, including pilot aids for mission control and management, in order to test the validity of the model, and to establish its sensitivity and diagnostic power. Conclusions are drawn about interface design

requirements affecting pilot-aiding and mission performance.
Author

N92-27899# Mitre Corp., Bedford, MA.
TECHNOLOGY AND STANDARDS FOR A COMMON AIR MISSION PLANNER
ELLEN K. KRIEGEL and JOSEPH K. DEROSA *In* AGARD, Air Vehicle Mission Control and Management 17 p (SEE N92-27887 18-01) Mar. 1992 Sponsored by AFSC
(AGARD-CP-504) Copyright Avail: CASI HC A03/MF A03

The USAF Electronics System Division (ESD) is currently developing a common air mission planner in a phased program for multiple aircraft and weapons. It is called Air Force Mission Support System (AFMSS) and will be used by the Strategic Air Command, Tactical Air Forces, Military Airlift Command, and Special Operations Forces of the United States. Discussed are the common elements that constitute the core of that mission planning system, as well as the accommodation of unique elements for each different aircraft. The open system architecture concept is established, and the technology trends and standards that drive the architecture are defined. Performance issues are discussed, and the Common Mapping System is presented. Finally, future challenges in mission planning systems are discussed. Author

N92-32438# National Defence Headquarters, Ottawa (Ontario).
OPERATIONAL NEEDS FOR AN UNMANNED AIR VEHICLE
L. R. MADER *In* AGARD, Integrated Target Acquisition and Fire Control Systems 9 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A01/MF A02; 1 functional color page

In order for sound and timely decisions to be made, commanders and staffs require a continuous source of information about the tactical situation they are facing. Unmanned Air Vehicle (UAV) technology offers a potential solution to augment a commander's surveillance resources. UAV's offer the land force commander the possibility of conducting wide range surveillance and target acquisition in near real time. UAV's will extend the range of observed fire to the limits of available weapons. Maritime forces could employ UAV's from or in support of small ships to augment manned aircraft. Examined here are the requirements for UAV's to support both land and marine operations. The characteristics and concepts of employment which make UAV's desirable for military applications are discussed. Author

N93-11711# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
AGARD FLIGHT TEST TECHNIQUES SERIES. VOLUME 10: WEAPON DELIVERY ANALYSIS AND BALLISTIC FLIGHT TESTING [L'ANALYSE DU LARGAGE D'ARMES ET LES ESSAIS EN VOL BALISTIQUE]
R. J. ARNOLD (Air Force Systems Command, Eglin AFB, FL.) and J. B. KNIGHT (Air Force Systems Command, Eglin AFB, FL.) Jul. 1992 170 p
(AGARD-AG-300-VOL-10; ISBN-92-835-0677-4; AD-A256156) Copyright Avail: CASI HC A08/MF A02

This volume in the AGARD Flight Test Techniques series treats stores ballistic modeling/testing from the overall system standpoint. All aspects of the ballistic testing design, data collection techniques, data reduction, analysis techniques, and finally the Operational Flight Program modeling techniques are addressed. Considerable effort has been expended to keep this report straightforward so that it can be understood by management as well as engineering personnel, but with sufficient engineering principles addressed so that a true ballistician could use it from an application perspective. This AGARDograph has been sponsored by the Flight Mechanics Panel of AGARD. Author

N93-28852# GEC Ferranti, Edinburgh (Scotland). Radar Systems Div.
PLANNING FOR AIR TO AIR COMBAT
I. D. GRAY *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 13 p (SEE N93-28850 11-54) Apr. 1993
(AGARD-CP-520) Copyright Avail: CASI HC A03/MF A03

Air combat planning has always proven very difficult because of the dynamic environment, intelligent adversaries, group operations, and the incomplete nature of any information. Two approaches, those of 'expert systems' and classical adversary search are presented and compared. Searching is then described and developed in detail. The implications of such an approach are considered for the future of air combat. Derived from text

N93-28854# GEC Sensors Ltd., Basildon (England).
A NEW CLASS OF MISSION SUPPORT FOR COMBAT AIR-CREW
HARVEY J. PIPE *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 6 p (SEE N93-28850 11-54) Apr. 1993
(AGARD-CP-520) Copyright Avail: CASI HC A02/MF A03

In the next century, combat aircraft will be even more complex than those planned as current replacements; this is to counter increasingly competent aggressors, who may operate anywhere in the world. This paper covers the integration of a mission management aid (MMA) into future combat aircraft, its operation, the core topics of Sensor Fusion, Situation Assessment (including Dynamic Threat Assessment), Planning and Tactical Routing (with Defense/Attack Options Management). Evaluation of the MMA is showing that better situation awareness is obtained, increasing mission effectiveness and survivability, and that overall the MMA is a vital integral system for future aviation. Derived from text

N93-28868# Thomson-CSF, Trappes (France). Dept. Simulateurs.
COMPUTER ASSISTED EVALUATION FOR AIR CLOSE COMBAT BASED ON TIME INTERVAL CHARACTERIZATION [EVALUATION AUTOMATIQUE DE COMBATS AERIENS FONDEE SUR LES INTERVALLES CARACTERISTIQUES]
P. POUTIGNAT and H. DEFONTENILLES *In* AGARD, Combat Automation for Airborne Weapon Systems: Man/Machine Interface Trends and Technologies 9 p (SEE N93-28850 11-54) Apr. 1993 In FRENCH
(AGARD-CP-520) Copyright Avail: CASI HC A02/MF A03

The complexity of modern military simulations poses a formidable debriefing task. A study was therefore conducted to demonstrate feasibility of an evaluation aid system for close air-to-air combat analysis. This analysis is based on a new concept of Time Interval Characterization (TIC). This concept is an extension of the method of breaking down a combat sequence into individual maneuvers. The TIC concept is also generic enough to ensure that the proposed aid system is adequate for every type of mission, and not only in the very specific domain of aircraft close-in combat. The analysis system does principally: (1) a measurement of pilot performance; (2) an extraction of characteristical intervals; (3) a detection of good or bad behavior according to expertise rules of debriefing; and (4) an optional generation of alternative trajectories by an aircraft combat expert system. Results obtained during these stages can be fully exploited with the interactive Man Machine Interface (MMI) which forms a part of the aid system. Expertise rules and MMI were defined in consultation with relevant experts.
Author (revised)

N94-25008# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
NEW ADVANCES IN MISSION PLANNING AND REHEARSAL SYSTEMS [LES NOUVELLES APPROCHES POUR LES SYSTEMES DE PLANIFICATION ET DE SIMULATION DES MISSIONS]
Oct. 1993 125 p Lectures held in Kjeller, Norway, 11-12 Oct. 1993, in Madrid, Spain, 14-15 Oct. 1993, and in Hanscom AFB, MA, 28-29 Oct. 1993
(AGARD-LS-192; ISBN-92-835-0723-1) Copyright Avail: CASI HC A06/MF A02

Modern data processing technology with greatly enhanced capabilities is being used in both the airborne and ground-based segments of the NATO Air Forces. A key element in the interface between these segments is provided by the mission planning systems which are used to analyze, fuse, and refine the information at air bases. The synergy of modern avionics systems and ground-based data networks cannot be fully realized unless mission data are provided effectively and rapidly to aircraft before the mission is commenced. Aircrew workloads must be minimized by the development of user-friendly planning systems which incorporate rehearsal facilities. To present some of the design and engineering aspects of mission planning systems, with particular emphasis on human factors considerations, examples

of modern mission planning and rehearsal systems will be described. For individual titles, see N94-25009 through N94-25016.

N94-25009# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
OVERALL SYSTEM CONCEPTS IN MISSION PLANNING
STEPHAN E. KOLITZ and ROBERT M. BEATON *In* AGARD, New Advances in Mission Planning and Rehearsal Systems, 17 p (SEE N94-25008 06-66) Oct. 1993
(AGARD-LS-192) Copyright Avail: CASI HC A03/MF A02

This paper describes the fundamental system concepts that are useful in addressing future growth areas of mission planning systems as reported in Section 2.1 of the AGARD Advisory Report 313 'Mission Planning Systems for Tactical Aircraft' (Pre-Flight and In-Flight). A significant requirement for mission planning systems, especially for autonomous vehicles, is the ability to quickly plan and/or replan a complex task or mission. Fast, efficient replanning is especially important because the state of the world can change abruptly and radically during the course of a mission. Mission planning systems must embody the capabilities necessary to swiftly replan actions in order to accommodate a vehicle's changing health or environment while continuing to pursue mission objectives. The complexity of mission planning problems has led to the use of hierarchical decompositions to make those problems manageable. The hierarchical approach to decision-making decomposes a large problem into a number of separate levels or sub-problems, thereby reducing the overall complexity, ideally without compromising overall system performance. In this lecture paper, an architecture for a mission planning system is presented with descriptions of the associated planning algorithms and planning management functions. Author (revised)

N94-25010# Royal Air Force, Farnborough (England). Inst. of Aviation Medicine.
HUMAN FACTORS OF MISSION PLANNING SYSTEMS: THEORY AND CONCEPTS
R. M. TAYLOR *In* AGARD, New Advances in Mission Planning and Rehearsal Systems 22 p (SEE N94-25008 06-66) Oct. 1993
(AGARD-LS-192) Copyright Avail: CASI HC A03/MF A02

Human factors of advanced Mission Planning Systems (MPS) are considered from a theoretical and conceptual point of view. MPS's are treated as a class of human-machine systems concerned with the functions of planning and rehearsal of mission tasks. The functions of planning and rehearsal are considered in relation to decision-making and actions in dynamic situations. Planning and rehearsal are essential for the identification and clarification of mission goals. Planning and rehearsal are cognitive tasks involving the skills of reasoning, decision-making, visualization, and mental simulation, with associated human capabilities and limitations. Performance of these preparatory cognitive skills reduces in-flight workload and affects the availability, quality, and structure of mission-relevant knowledge. Knowledge and understanding gained during planning influences the performance of in-flight mission tasks. Perceptions of mission problems and situations are initially formulated during planning and rehearsal. Inappropriate perceptions result in inappropriate plans, reduced in-flight situational awareness, erroneous decisions, and degraded mission performance. The psychology of systems design is reviewed with reference to MPS requirements. Particular attention is given to the role of automation and aiding technology in the performance of planning and rehearsal tasks. The nature of air crew involvement in MPS decision making is a key system design issue determining mission effectiveness. Relevant human capabilities and limitations, and the level of air crew active involvement and machine autonomy, need to be carefully considered in initial systems design. A human-systems design paradigm based on principles of adaptive aiding and co-operative functioning is proposed for advanced MPS design. The cognitive compatibility of the air crew task and system interface is a key requirement for effective air crew involvement in MPS processes and for successful MPS functioning. Author (revised)

N94-25011# British Aerospace Defence Ltd., Farnborough (England).
HUMAN FACTORS OF MISSION PLANNING SYSTEMS: APPLICATIONS AND IMPLEMENTATION
I. ROSS *In* AGARD, New Advances in Mission Planning and Rehearsal Systems 7 p (SEE N94-25008 06-66) Oct. 1993
(AGARD-LS-192) Copyright Avail: CASI HC A02/MF A02

It was apparent from the beginning of the work carried out by the Joint Working Group in Phase One, that the successful application and implementation of human factors considerations were an essential part of the design of Mission Planning Systems (MPS). Although these considerations were discussed in Phase One, in Phase Two human factors were investigated in greater detail. It was considered essential that, as with all systems design, a full understanding of the information requirements and information flow of MPS's in Pre-flight, In-flight, and Post-flight situations was understood, as well as the dependencies under which the system must operate. Ideally, each component should be complimentary and be designed in accordance with requirements of each component as well as the 'mission' system as a whole. The Phase One report included descriptions of the emerging MPS including the ergonomics and the interface of each system. There was a high degree of similarity apparent in both approach and implementation. The Phase Two report explored many of the issues raised in greater detail, particularly that of trust that aircrew must have in the systems and the subsequently planned mission and the interface through which the user must communicate with the system. Author (revised)

N94-25012# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
COMPUTING TECHNIQUES IN MISSION PLANNING
STEPHAN E. KOLITZ *In* AGARD, New Advances in Mission Planning and Rehearsal Systems 20 p (SEE N94-25008 06-66) Oct. 1993
(AGARD-LS-192) Copyright Avail: CASI HC A03/MF A02

This lecture paper addresses issues related to the major concern stated in Section 5.1 of the AGARD Advisory Report 313 'Mission Planning Systems for Tactical Aircraft (Pre-Flight and In-Flight).' A major concern involving all aspects of mission planning systems is the tremendous computational burden that is required for a wide variety of mission planning functions. The approaches for solving the Mission Planning Problem can generally be grouped into two categories: approaches that guarantee optimality; and heuristic approaches that do not guarantee optimality. Useful solution methodologies can be characterized by polynomial running time complexity. This paper concentrates on computational issues that arise when using hierarchical decomposition to solve the Mission Planning Problem. An analytic methodology and sample analyses are presented for an abstract planning system. Author (revised)

N94-25013# Defence Research Agency, Farnborough, Hampshire (England).
MISSION PLANNING AND MISSION REHEARSAL SYSTEMS: DISPLAYS AND OTHER INTERACTIVE TECHNIQUES
GEOFFREY H. HUNT *In* AGARD, New Advances in Mission Planning and Rehearsal Systems 12 p (SEE N94-25008 06-66) Oct. 1993
(AGARD-LS-192) Copyright Avail: CASI HC A03/MF A02

Recent years have witnessed a very rapid growth in the power of computer-based systems of all types. This rapid growth has been based on faster devices, better interfaces, and the use of parallel processing. Mission planning systems have shared in this evolution and there is every reason to believe that, for the medium term at least, this increase in power will continue. The effective use of this power by the user implies that a proper collaboration is established between the user (man) and the system (machine) which can utilize to the maximum the particular capabilities of each. This requires that the greatest attention is given to the design of the interface between machine and user since the interface can significantly constrain the overall performance of the man-machine system. This lecture describes the man-machine interface technologies which are currently available to the developer of mission planning systems and provides descriptions of some of the advances in these technologies which are expected to become available in the short to medium term. Author (revised)

N94-25014# GEC Avionics Ltd., Rochester (England). Display Systems Group.
GROUND BASED MISSION PLANNING SYSTEMS
J. MILLIGAN and B. H. CAMP *In* AGARD, New Advances in Mission Planning and Rehearsal Systems 12 p (SEE N94-25008 06-66) Oct. 1993
(AGARD-LS-192) Copyright Avail: CASI HC A03/MF A02

For complex combined missions, it has been necessary for Ground Based Mission Planning to be performed as close to the individual mission as possible. With the advent of intelligent Automated Mission Planning Systems (AMPS) and reliable, secure communications, the speed of data exchange and completion of the subsequent mission planning has greatly increased. This paper outlines the mission cycle and briefly examines a range of mission tasking activity. This framework is used to describe a possible operating base tasking and planning system architecture, within which the AMPS architecture is explained. Typical AMPS databases and functions are examined before a description of the actual task definition and mission planning processes. Mission validation and rehearsal capabilities are outlined, and the range of data outputs is examined. The paper concludes by briefly explaining the archiving of the resulting data. Author (revised)

N94-25015# Dassault-Breguet Aviation, Saint-Cloud (France).
IN FLIGHT MISSION PLANNING IN THE COPILOTE ELECTRONIQUE
G. CHAMPIGNEUX *In* AGARD, New Advances in Mission Planning and Rehearsal Systems 12 p (SEE N94-25008 06-66) Oct. 1993
(AGARD-LS-192) Copyright Avail: CASI HC A03/MF A02

This paper describes the functional aspects and the engineering guidelines of an in-flight mission planning system. The system is being developed as a part of the French project known as 'Electronic Copilot.' This project is lead by Dassault Aviation with the support of French official services (DRET STTE) and involves many industrial and scientific partners. Emphasis is put on the in-flight Pilot-System relationship and dynamic task allocation. A few words are said about knowledge acquisition methodologies and tools that are suitable for the development of a cognitive planning assistant. Author (revised)

N94-25016# Evans and Sutherland Computer Corp., Salt Lake City, UT. Simulation Div.
MISSION REHEARSAL IN THE SOF-ATS PROGRAM
JOHN ELLIS *In* AGARD, New Advances in Mission Planning and Rehearsal Systems 8 p (SEE N94-25008 06-66) Oct. 1993
(AGARD-LS-192) Copyright Avail: CASI HC A02/MF A02

The USAF SOF-ATS program includes both aircrew training and mission rehearsal elements. Recent advances in computer image generation and database generation have made possible the rapid database construction and scene realism necessary for mission rehearsal. This paper describes the development of computer image generator technology from that used in military flight simulation to meet the needs of the SOF-ATS mission rehearsal system. Author

N94-28424# Naval Aviation HQ, Yeovil (England).
THE CONCEPT OF ROYAL NAVY AIR OPERATIONS UNDER EXTREME ENVIRONMENTAL CONDITIONS
A. P. STEELE-PERKINS *In* AGARD, The Support of Air Operations under Extreme Hot and Cold Weather Conditions 11 p (SEE N94-28420 08-51) Oct. 1993
(AGARD-CP-540) Copyright Avail: CASI HC A03/MF A03

The Fleet Air Arm of the Royal Navy has always operated on a worldwide basis, with environmental extremes and therefore the accompanying stressors. Its procedures and essential support, including equipment and aviation medicine, have evolved to ensure a safe and efficient modus operandi. The post cold war concept of operations has proved the original philosophy. Recent events are discussed together with the aviation medicine implications. Author

N94-34631# Eidetics International, Inc., Torrance, CA.
OPTIMAL TACTICS FOR AGILE AIRCRAFT TECHNOLOGY: A DIFFERENTIAL GAME METHODOLOGY
URBAN H. D. LYNCH *In* AGARD, Technologies for Highly Manoeuvrable Aircraft 8 p (SEE N94-34605 10-05) Mar. 1994
(AGARD-CP-548) Copyright Avail: CASI HC A02/MF A03

Historically, fighter aircraft tactics were not developed until a new aircraft reached operational use. In the past, this pilot/aircraft intensive process was affordable. In the future, budgets and limited flying time will likely necessitate a more cost-effective way to develop tactics for innovative and unfamiliar aircraft technologies. Such is the case for WVR technologies as high angle-of-attack (70 degrees) super maneuverability (X-31, F-18 HARV) and super maneuverable missiles (Archer-11, Aim-9X). The advent of very high, cost-effective computer power has made affordable optimal control techniques (that have been traditionally computationally prohibitive) and low-cost real-time piloted simulation of credible realism. Together, these two tools provide a cost-effective means to develop tactics for new technology prior to the new technology reaching the field in operational use. This paper presents the successful results of a first attempt to use Differential Games (the Eidetics AACDG) and the Eidetics low-cost ARENA simulator to develop new tactics for new technology such as extended flight maneuvering, (EFM). This work was sponsored by the Four-Power Senior National Representatives (SNR) through Aeronautical Systems-Center at Wright-Patterson Air Force Base, Ohio, USA. Author (revised)

N94-36337# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany). Inst. for Aerospace Medicine.
EXTENDED RANGE OPERATIONS: A REVIEW OF RECENT DEVELOPMENTS
A. SAMEL and H. M. WEGMANN *In* AGARD, Recent Advances in Long Range and Long Endurance Operation of Aircraft 10 p (SEE N94-36321 11-05) Nov. 1993
(AGARD-CP-547) Copyright Avail: CASI HC A02/MF A03

The introduction of long-haul aircraft which can be operated by a 2-crew flight deck over expanded duty hours, raises serious concerns about flight safety. It is a matter of intense discussions between authorities, operator and pilot associations in the USA, in Japan and in Europe whether the legal standards of flight duty limitations presently in force are still adequate or must be modified for minimum crew operations under the changing conditions. In cooperation with various air carriers, different approaches have recently been undertaken by international scientific laboratories to investigate physiological and psychological responses of the human element to the new technology in the cockpit during long-haul operations. In the conventional 3-man cockpit, pre-planned controlled rest on the flight deck has been investigated. In augmented crews, comparison have been made between the 3-man flight deck and the newly introduced 2-crew cockpit. The efficiency of onboard rest facilities has been investigated during long-haul augmented 2-crew operations. Workload, alertness and fatigue are under investigation in single 2-crew operations with non-stop flights of up to 14 hours flight duty time. Because not all of these investigations are completed, scientific contributions for discussions about flight time limitations and rest requirements must still be limited. However, in certain countries, scientific results have already led to recommendations for amendments in the actual legislation. Author

N94-36633# British Aerospace Defence Ltd., Preston (England). Military Aircraft Div.
SENSOR DATA FUSION FOR AIR TO AIR SITUATION AWARENESS BEYOND VISUAL RANGE
C. A. NOONAN, M. E. EVERETT, and R. C. FREEMAN *In* AGARD, Pointing and Tracking Systems 8 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02

A modern tactical aircraft is faced with ever increasing threats and, to be effective against them, it needs to know what and where they are as early as possible during any encounter. It must do this day and night, in all weather, in hostile countermeasure environments and in the presence of clutter. Tactical aircraft receive large amounts of information from multiple sensors and data communications systems. To allow the crew to manage the aircraft and ensure its mission is fulfilled, the information must be aligned,

correlated, consolidated and presented to them in a meaningful form. The paper introduces a model of tactical situation awareness processing which comprises sensors, data fusion, situation assessment and sensor management. The purpose of each component of the model and the relationships between them are discussed. The requirements placed on sensor data fusion by air to air sensing are discussed, and so is the way in which they are dominated by particular features of the tactical aircraft platform and its mission. The influence of these factors on the design of air to air situation awareness systems is considered. A computer test harness, developed by BAe Defence, Military Aircraft Division, is described, along with built-in tools which calculate test statistics. The harness was developed as part of a program of studies carried out by the Mission Systems group of the Design Quality and R&D team within the Systems Engineering Department at BAe's Warton unit in Lancashire, U.K. Examples of the results which were obtained when an air to air sensor data fusion model was evaluated are reproduced. These take the form of graphs and diagrams representing test statistics and offer a means by which different solutions to various data fusion problems may be compared under identical conditions. Author

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PHYSICS (GENERAL)

N94-11490# GEC Hirst Research Centre, Wembley (England). Long Range Research Lab.
CHAOTIC TIME SERIES ANALYSIS
JAROSLAV STARK *In* AGARD, Stability in Aerospace Systems 11 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A03/MF A03

This paper begins with a brief description of the basic theoretical framework for analyzing chaotic time series and then goes on to discuss recent work in this area in the Long Range Research Laboratory. As a particular example, we shall show how the ability to make short term predictions of chaotic time series can be used to extract small signals from a complex deterministic background. Experiments with simulated data have shown that it is possible to recover signals to a reasonable accuracy in situations where the ratio of amplitudes of signal to chaotic background is as low as 10(exp -5):1. Derived from text

N94-11495# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Directiondes Etudes de Synthese.
CHAOS, ENTROPY, AND REVERSIBILITY: A SIMPLE EXAMPLE
C. MARCHAL *In* AGARD, Stability in Aerospace Systems 3 p (SEE N94-11489 01-08) Feb. 1993
(AGARD-R-789) Copyright Avail: CASI HC A01/MF A03

The contradiction between mathematical reversibility and physical irreversibility has traditionally led to the suspicion of 'hidden correlations' that will allow, in some cases, the decrease of the entropy of isolated systems. This idea seems wrong, as shown by a very simplified model. The true reason of the physical irreversibility is certainly the very large number of parameters of irreversible systems. Derived from text

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ACOUSTICS

Includes sound generation, transmission, and attenuation.

N93-10666# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
COMBAT AIRCRAFT NOISE [LE BRUIT GENERE PAR LES AVIONS DE COMBAT]
Apr. 1992 363 p In ENGLISH and FRENCH The 78th meeting was held in Bonn, Fed. Republic of Germany, 23-25 Oct. 1991
(AGARD-CP-512; ISBN-92-835-0667-7; AD-A253108) Copyright Avail: CASI HC A16/MF A03

The Conference Proceedings contain 26 papers presented at the Propulsion and Energetics Panel 78B Specialists' Meeting on 'Combat Aircraft Noise' which was held 23-25 Oct. 1991 in Bonn, Germany. Noise emission from combat aircraft during low-altitude, high-speed training missions over populated areas has led to massive complaints. The purpose of the meeting was to offer a forum for specialists to discuss the latest state of the technology concerned and--if possible--to find solutions for overcoming the problems. The Specialists' Meeting was composed of the following sessions: User's Demand, Experience of Noise Effects; Mechanisms of Noise Generation; Noise Measurements, Predictions Methods; and Noise Reduction. Questions and answers of the discussions follow each paper in the Proceedings. For individual titles, see N93-10667 through N93-10692.

N93-10667# Bundesministerium der Verteidigung, Bonn (Germany).
COMBAT AIRCRAFT OPERATIONS: TRAINING REQUIREMENTS FOR THE GERMAN AIR FORCE TACTICAL FLYING UNITS AND THE NOISE PROBLEM
W. JERTZ *In* AGARD, Combat Aircraft Noise 5 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A01/MF A03

The deterrence potential of an Air Force, and by that the capability to fulfill their mission in times of war, relies on threat oriented training in peacetime. Low level flying is a major tactical means to help aircrews reduce the anticipated threat imposed to them by enemy air defence systems to an acceptable degree. The demand for this capability applies also to air defence tasks against attacking fighter bombers. Military low level flying requires a high degree of proficiency, which can only be reached and maintained by constant training. A high performance level is then the key to air power. The possibilities for this kind of necessary training are restricted by superior demands concerning, amongst others, flying safety and environmental reasons. Too intensive restrictions might reduce the fighting capability of the wings to such an extent, that mission fulfillment could be seriously endangered. Author

N93-10669# Royal Air Force, London (England).
COMBAT AIRCRAFT NOISE: THE OPERATOR'S PERSPECTIVE
R. BOGG *In* AGARD, Combat Aircraft Noise 9 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A02/MF A03

Combat aircraft are not subject to the same noise reduction regulations as civil aircraft. Additionally, combat aircraft are operated closer to their performance limits and at high power settings for extended periods. There is general pressure to reduce noise of all kinds, but particularly noise from low flying aircraft. Although there is little that can be done to quiet in-service engines, operational palliatives, such as noise abatement procedures and restrictions on low flying, have been introduced. Moreover, there has been a concerted education and public relations campaign, and numerous airspace management changes have been introduced to reduce the impact of low flying on the population. These subjects were considered during a Pilot Study into aircraft noise under the auspices of the NATO Committee on the Challenges of Modern Society; the findings of the Study are discussed, giving both the international viewpoint and the UK

perspective in particular. Some options for the reduction of low flying are also considered, but so long as military aircraft need to fly low to evade enemy air defences, low flying will remain a principal tactic of NATO air forces, and peacetime training will remain an essential military requirement. Thus, noise from low flying combat aircraft will remain a sensitive issue, and ways of reducing it will continue to be of importance for many years to come. Author

N93-10670# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.
HUMAN NOISE EXPOSURE CRITERIA FOR COMBAT AIRCRAFT TRAINING AREAS
ROBERT A. LEE, C. STANLEY HARRIS, and HENNING E. VONGIERKE *In* AGARD, Combat Aircraft Noise 12 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03
An overview of interpretive criteria for the noise exposure conditions associated with low altitude flying operations in the United States is presented. It includes description of single event and cumulative noise characteristics unique to such flying activity and a discussion of rationale for using the measure, onset rated adjusted Day-Night Average Sound Level, for predicting population annoyance. Author

N93-10671# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France).
NOISE OF COMBAT AIRCRAFT IN PROXIMITY TO AIR BASES: REVIEW OF THE POSSIBILITIES OF NOISE REDUCTION AT THE SOURCE [BRUIT DES AVIONS DE COMBAT A PROXIMITE DES BASES AERIENNES: REVUE DES POSSIBILITES DE REDUCTION DU BRUIT A LA SOURCE]
D. COLLIN, J. JULLIARD, and G. RIOU *In* AGARD, Combat Aircraft Noise 11 p (SEE N93-10666 01-71) Apr. 1992 In FRENCH
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03
The operations carried out by combat aircraft are a source of nuisance for the populations situated in proximity to air bases. The noise of jet aircraft constitutes the dominant source of noise in the operations in question. The authors propose to approach the question of the reduction of the corresponding sonic nuisances by utilizing experience acquired by SNECMA over the course of more than twenty years of research on the noise of civil jet turbine engines, and especially of the Concorde supersonic transport program. The important experimental database resulting from these studies has permitted the development and evaluation of preview methods and solutions in noise reduction. The different mechanisms and significant sources of noise will therefore be reviewed at the same time as the possibilities for current or future improvement. Author

N93-10672# National Research Council of Canada, Ottawa (Ontario). Inst. for Mechanical Engineering.
NOISE STUDIES FOR ENVIRONMENTAL IMPACT ASSESSMENT OF AN OUTDOOR ENGINE TEST FACILITY
G. KRISHNAPPA *In* AGARD, Combat Aircraft Noise 8 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A02/MF A03
The potential impact of noise in the community surrounding a proposed outdoor test facility in the Ottawa area was evaluated. The test stand was planned for the testing of high performance gas turbine engines. Theoretical predictions based on the outdoor sound propagation model were made for the noise generated from a General Electric F404 engine. The results were verified by carrying measurements of noise generated from a single engine of a parked CF-18 aircraft. The measured results qualitatively confirmed the validity of theoretical predictions. However, the tests clearly demonstrated the strong influence of the atmospheric conditions in the observed noise levels in the surrounding community. The usefulness of the theoretical predictions in devising noise control measures in the test area and for the scheduling of tests in favorable weather conditions to minimize noise impact in the surrounding area were discussed. Author

N93-10673*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NON-PROPULSIVE AERODYNAMIC NOISE
WILLIAM L. WILLSHIRE, JR. and MAUREEN B. TRACY *In* AGARD, Combat Aircraft Noise 24 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03
In the first part of the paper, the contribution of airframe noise to total aircraft noise on approach is assessed for a large current technology transport and for the same airframe powered with bypass ratio 10 engines with an additional 5 dB noise suppression applied to the fan and turbine noise sources. The airframe noise of the envisioned advanced subsonic transport is 2 EPNdB less than the largest contributor to the total aircraft noise, the fan inlet. The noise impact of the airframe noise, as measured by noise contour area, is 1/4 that of fan noise. Further fan noise reduction efforts should not view airframe noise as an absolute noise floor. In the second part of the paper, the results from one recent cavity noise wind tunnel experiment is reported. A cavity of dimensions 11.25 in. (28.58 cm) long, 2.5 in. (6.35 cm) wide, and variable depth was tested in the Mach number range of .20 through .90. Reynolds number varied from 5 to 100 million per foot (16 to 328 million per meter). The 1/d ratio was varied from 4.4 to 20.0. The model was tested at yaw angles from 0 to 15 degrees. In general, the deeper the cavity, the greater the amplitude of the acoustic tones. Reynolds number appeared to have little effect on acoustic tone amplitudes. Tone amplitude and bandwidth changed with Mach number. The effect of yaw on acoustic tones varied with Reynolds number, Mach number, 1/h, and mode number. At Mach number 0.90, increased yaw shifted the tone frequencies of the higher modal frequencies to lower frequencies. As cavity depth decreased, the effect of yaw decreased. Author

N93-10674# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Inst. fuer Entwurfsaerodynamik.
COMPARISON OF FLYOVER NOISE DATA FROM AIRCRAFT AT HIGH SUBSONIC SPEEDS WITH PREDICTION
JAN BOETTCHER and ULF MICHEL (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Berlin, Germany) *In* AGARD, Combat Aircraft Noise 12 p (SEE N93-10666 01-71) Apr. 1992 Sponsored in part by Bundesminsterium der Verteidigung
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03
Flyover noise measurements are evaluated for four different military jet aircraft types flying at low altitudes. Flight Mach numbers ranged from 0.5 to 0.9. The analysis shows that noise emission is caused by jet mixing and broadband shock associated noise. Based on the experimental results, existing noise prediction schemes are extended toward higher subsonic flight Mach numbers. The novel prediction schemes describe the observed acoustic signatures quite accurately. This holds for the overall sound pressure level independently of the emission angle, for sound-pressure level time histories and for one-third-octave spectra. Author

N93-10675# Technische Univ., Berlin (Germany).
NOISE EMISSION OF LOW FLYING MILITARY AIRPLANES
H.-D. MAROHN *In* AGARD, Combat Aircraft Noise 11 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03
Until the end of 1990 a great amount of low altitude flying of military airplanes was done in the Federal Republic of Germany. Up to then approximately 80,000 low altitude flights were performed annually. Many of these flights took place at a height from 500 ft to 1500 ft. Nearly 2/3 of the whole area of the Federal Republic of Germany was used for low altitude flights between 500 ft and 1500 ft. In seven distinct low flying areas flights even down to a height of 250 ft above ground were allowed. In a relative densely populated country these low altitude flights caused a great amount of disturbance and annoyance. In order to have some information on noise emission of military airplanes flying at subsonic speed at low altitude a measurement campaign was done in the vicinity of the shooting range in Meppen. A special aim of the campaign was to obtain insight into the influence of operational parameters on the noise emission during low altitude flights. The results of these measurements, for instance noise emission as a function of speed and height above around, will be presented. In general, people affected by low altitude flights would not often receive extremely high noise levels because only a part of the population

was exposed to direct overflights. It was therefore of interest to determine the number of occurrences and the statistical distribution of noise levels experienced by people living in low flying areas of Germany. For this purpose a research activity was performed in Germany in the years 1986 and 1990. During six weeks at 16 locations within four low flying areas continuous noise measurements were made. The results, such as relative frequency of noise levels and noise duration, are to be presented. Author

N93-10676# Dassault (E. M.) Co., Saint-Cloud (France). Division Acoustique.

COMBAT AIRCRAFT NOISE [BRUIT DES AVIONS DE COMBAT]

M. SGARBOZZA and A. DEPITRE (Direction Generale de l'Aviation Civile, Paris, France) *In* AGARD, Combat Aircraft Noise 12 p (SEE N93-10666 01-71) Apr. 1992 In FRENCH

(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

A discussion of the characteristics and the noise levels of combat aircraft and of a transport aircraft in taking off and landing are presented. Some methods of noise reduction are discussed, including the following: operational anti-noise procedures; and concepts of future engines (silent post-combustion and variable cycle). Some measurement results concerning the noise generated in flight at great speeds and low altitude will also be examined. Finally, the protection of the environment of French air bases against noise will be described and the possibilities of regulation examined. Author

N93-10677# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).

BOOM AND THE PROBLEMS RELATED TO THE SUPERSONIC FLIGHTS OF MILITARY AIRCRAFT [LE BANG ET LES PROBLEMES LIES AUX VOLS SUPERSONIQUES DES AVIONS MILITAIRES]

CHRISTIAN THERY and CLAUDE LECOMTE *In* AGARD, Combat Aircraft Noise 27 p (SEE N93-10666 01-71) Apr. 1992 In FRENCH

(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

The flight of a supersonic projectile is accompanied by a clapping called ballistic detonation. At the same time an aircraft in supersonic flight creates a boom which travels to the ground. The boom represents an impulsional characteristic which provokes a startled reaction in living beings and makes structures vibrate. Because of the elevated altitude of the flight of aircraft the boom is felt along a band of terrain situated along each side of the trajectory of the aircraft, as large as many tens of kilometers. The intensity of the boom essentially depends on the size of the aircraft that creates it, on its altitude, and on the maneuver that it is executing; the maneuvers which are executed by military aircraft provoke locally a very great intensification of booms, these are focalizations and superfocalizations. These phenomena appear especially at the time of transonic acceleration and when turning. The annoyance resulting from these focalized booms is therefore certain and related damage to aging or poorly constructed structures can occur; the sole means of limiting the nuisance which results will be to situate these focalized boom zones over uninhabited regions. A good preview of the affected zones requires precise a priori knowledge of the actual trajectory of the aircraft and the meteorological conditions; in practice therefore, the zones susceptible to being affected by these phenomena are fairly large. Above all, the effects of boom must not be overestimated. The first temporary damages to the auditory system are observed for levels of wave intensity greatly superior to the levels of booms (3000 to 5000 Pa as opposed to 50 or 70 Pa for a boom). The structural effects of normal booms are comparable to those resulting from natural inclemency (wind) or related to modern life (highway traffic). The focalized boom cannot have an impact on sound and well-constructed buildings except by cumulative effect (fatigue). Author

N93-10678# Royal Aircraft Establishment, Farnborough (England). Aerospace Division.

A BRIEF REVIEW OF THE SOURCE NOISE TECHNOLOGY APPLICABLE TO FIXED-WING MILITARY AIRCRAFT

R. A. PINKER *In* AGARD, Combat Aircraft Noise 14 p (SEE N93-10666 01-71) Apr. 1992

(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

Although the last two decades have seen major reductions in the noise from civil aircraft, noise from military operations, both around airfields and from low-flying aircraft, continues to be a source of irritation and a potential health hazard. Because of the continuing concern about the noise levels produced by combat aircraft, the following paper is intended to provide some of the background to the main conclusions and recommendations reached in the final report of the NATO/Committee on the Challenges of a Modern Society (CCMS) Pilot Study on aircraft noise. Although biased towards fixed wing combat aircraft noise, the paper also considers other fixed wing military aircraft, but specifically excludes sonic booms and rotary wing aircraft as they both have their own particular noise sources and problems. Author

N93-10679# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).

COMBAT AIRCRAFT JET ENGINE NOISE STUDIES [ETUDES SUR LE BRUIT DES TURBOREACTEURS APPLICABLES AUX AVIONS DE COMBAT]

S. LEWY, G. FOURNIER, and M. PIANKO (Icare, Massy, France) *In* AGARD, Combat Aircraft Noise 17 p (SEE N93-10666 01-71) Apr. 1992 In FRENCH Previously announced in IAA as A92-26353

(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

Methods of noise prediction and attenuation based on results obtained in civil applications are presented. Input data for directivity and radiation forecasts are given by measurements of vane and blade pressure fluctuations and by modal analysis of the spinning waves propagating in the inlet duct. Attention is given to sound generation mechanisms for subsonic and supersonic single jets and bypass jets. Prediction methods, based on Lighthill's equation (tensor due to the turbulence), are discussed, and the various means of jet noise reduction are reviewed. The CEPRA 19 anechoic wind tunnel, which is primarily designed for studying the jet noise radiated in the far field with flight effects is described. Author

N93-10680*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

SUPERSONIC ACOUSTIC SOURCE MECHANISMS FOR FREE JETS OF VARIOUS GEOMETRIES

JOHN M. SEINER and MICHAEL K. PONTON *In* AGARD, Combat Aircraft Noise 12 p (SEE N93-10666 01-71) Apr. 1992

(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

The aeroacoustic performance of several generic nozzle geometries was tested to evaluate the potential benefits of using non-round jet exit geometries to reduce noise from combat military aircraft. Both the aerodynamics and far field acoustics of several M(sub d) = 1.5 and 2.0 round, elliptic, and rectangular nozzles, including an augmented deflector exhaust nozzle (ADEN), were studied to assess noise emission. The nozzles were operated to jet total temperatures, T(sub 0) = 1160 degree R, and the data scaled to constant thrust. The data were propagated to 1500 ft. and corrected to perceived noise level. The aerodynamic results of the study show that the non-round nozzle geometries mix much faster with the surrounding medium than does an equivalent round nozzle plume. Both the ADEN and elliptic nozzles provide significant reduction of noise, 6 to 7 PNdB, along the major axis direction with little expected impact on nozzle performance. Shock noise processes are eliminated for elliptic nozzles, but are still significant with rectangular nozzles. Comparison of measurements to theoretical predictions of noise using the quasi-linear instability wave model demonstrates good qualitative agreement. Author

N93-10681# Illinois Inst. of Tech., Chicago, IL. Dept. of Mechanical and Aerospace Engineering.
NOZZLE INSTALLATION EFFECTS ON THE NOISE FROM SUPERSONIC EXHAUST PLUMES
R. W. WLEZIEN *In* AGARD, Combat Aircraft Noise 11 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

The sensitivity of screech coupling in supersonic jets to nozzle installation geometry is explored as a function of nozzle shape, spacing, and orientation. The coupling phenomenon is shown to be a function of geometry for a variety of twin axisymmetric and rectangular nozzle configurations as well as for a single jet in proximity to a solid surface. Rapid plume merging or close proximity to a wall are shown to minimize the noise increment due to coupling. Twin impinging supersonic plumes experience more complex aeroacoustic interactions. The acoustic near field is dominated by screech and impingement tones, but the fuselage undersurface dynamic loads are primarily due to impingement of the unsteady upwash fountain flow on the fuselage undersurface. Author

N93-10682*# California Inst. of Tech., Pasadena, CA.
COMBUSTION NOISE AND COMBUSTION INSTABILITIES IN PROPULSION SYSTEMS
F. E. C. CULICK, L. PAPARIZOS (Carnegie-Mellon Univ., Pittsburgh, PA.), J. STERLING, and V. BURNLEY *In* AGARD, Combat Aircraft Noise 27 p (SEE N93-10666 01-71) Apr. 1992 Sponsored in part by NASA, California Inst. of Technology; Navy; and AF
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

This paper is concerned with some aspects of non-linear behavior of unsteady motions in combustion chambers. The emphasis is on conditions under which organized oscillations having discrete frequencies may exist in the presence of random motions. In order to treat the two types of motions together, and particularly to investigate coupling between noise and combustion instabilities, the unsteady field is represented as a synthesis of acoustic modes having time-varying amplitudes. Each of the amplitudes are written as the sum of two parts, one associated with the random field and the remainder representing the organized oscillations. After spatial averaging, the general problem is reduced to solution of a set of second-order ordinary differential equations whose structure depends on the sorts of nonlinear processes accounted for. This formulation accommodates any physical process; in particular, terms are included to represent noise sources, although only limited modeling is discussed. Our results suggest that random sources of noise have only small effects on combustion instabilities and seem not to be a cause of unstable motions. However, the coupling between the two sorts of unsteady motions may be important as an essential process in a proposed scheme for noise control. It is now a familiar observation that many nonlinear deterministic systems are capable of exhibiting apparently random motions called 'chaos.' This is a particularly interesting possibility for systems which also executed non-deterministic random motions. In combustion chambers, a nonlinear deterministic system (acoustical motions) exists in the presence of noise produced by flow separation, turbulent motions, and energy released by combustion processes. The last part of the paper is directed to the matter of discovering whether or not chaotic motions exist in combustion systems. Analysis has not progressed sufficiently far to answer the question. We report here recent results of processing data taken in one combustor to determine the dimensions of any attractors in the motions. No evidence has been found for chaos in the strict sense, but the method seems to be an important means of investigating the nonlinear behavior of combustion systems. Author

N93-10683# Bolt, Beranek, and Newman, Inc., Canoga Park, CA.
AUDIBILITY-BASED ANNOYANCE PREDICTION MODELING
SANFORD FIDELL and LAWRENCE S. FINEGOLD (Air Force Systems Command, Wright-Patterson AFB, OH.) *In* AGARD, Combat Aircraft Noise 9 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A02/MF A03

The effects of rapid onset times and high absolute sound pressures near military training routes (MTR's) including possible startle effects and increased annoyance due to the unpredictable nature of these flights, have been of longstanding concern. A more recent concern is the possibility of increased annoyance due to low ambient noise levels near military flight training operations and differences in expectations about noise exposure in high and low population density areas. This paper describes progress in developing audibility-based methods for predicting the annoyance of noise produced at some distance from aircraft flight tracks. Audibility-based models which take into account near-ground acoustic propagation and ambient noise levels may be useful in assessing environmental impacts of MTR's and Military Operating Areas (MOA's) under some conditions. A prototype Single Event Annoyance Prediction Model (SEAPM) has been developed under USAF sponsorship as an initial effort to address these issues, and work has progressed on a geographic information system (GIS) to produce cartographically referenced representations of aircraft audibility. Author

N93-10684*# Pennsylvania State Univ., University Park, PA. Dept. of Aerospace Engineering.
THE PREDICTION OF NOISE RADIATION FROM SUPERSONIC ELLIPTIC JETS
PHILIP J. MORRIS and THONSE R. S. BHAT *In* AGARD, Combat Aircraft Noise 12 p (SEE N93-10666 01-71) Apr. 1992
(Contract(s)/Grant(s): NAG1-1047)
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

This paper describes the prediction of noise radiation from supersonic elliptic jets. The noise is associated with the large scale structures in the jet mixing layer. These structures are described as instability waves. The local characteristics of the instability waves are determined from a compressible, linear, analysis. The jet mean velocity and density are described in elliptic cylindrical coordinates. The local eigensolution for the instability waves is determined from a finite difference solution of the non-separable boundary value problem. This inner solution which is formulated in terms of the method of multiple scales is matched with the radiated field using the method of matched asymptotic expansions. The form of the far-field directivity is derived. Predictions are presented for the noise radiation by the several modes of instability in the elliptic jet. The radiated field is not axisymmetric and certain modes radiate strongly in the directions of the major and minor axes of the jet. The extension of the present work to other geometries and flow fields is discussed. Author

N93-10685# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Berlin (Germany). Inst. fuer Experimentelle Stroemungsmechanik.
PREDICTION OF JET MIXING NOISE FOR HIGH SUBSONIC FLIGHT SPEEDS
ULF MICHEL and JAN BOETTCHER (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany) *In* AGARD, Combat Aircraft Noise 9 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A02/MF A03

A method for the prediction of single stream jet mixing noise in flight is presented that can be used for flight Mach numbers up to 0.9. The method is similar to the empirical SAE method. However, two important results of the theoretical scaling law of Michalke and Michel are incorporated: (1) the total noise of heated jets is separated into quadrupole and dipole noise components because they are influenced differently by the flight Mach number and, (2) the influence of the stretching of the jet plume in flight on the overall sound pressure and the frequency of the emitted sound is considered. A relative velocity exponent law is used to correlate experimental flyover data. The correlation is based on all available data for combat aircraft with fuselage mounted engines and flight Mach numbers between 0.5 and 0.9. The difference between predictions with this new method and measured overall flyover levels is generally less than two decibels. The spectra are also well predicted. Author

N93-10686# Royal Aircraft Establishment, Farnborough (England). Aerospace Div.
IDENTIFYING THE PRINCIPAL NOISE SOURCES OF FIXED-WING COMBAT AIRCRAFT IN HIGH-SPEED FLIGHT
W. D. BRYCE, R. A. PINKER, and P. J. R. STRANGE (Rolls-Royce Ltd., Derby, England) *In* AGARD, Combat Aircraft Noise 20 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

Before considering means for alleviating the noise from modern military combat aircraft operating in high-speed low-level flight, it is important to identify the principal noise sources. To this end, a

carefully-controlled flight test program has been carried out using a Tornado aircraft (in standard training configuration) operating at flight speeds from 0.5M to 0.8M. The major sources of the aircraft noise, airframe noise, installed jet mixing noise and jet shock noise, have been successfully identified, quantified and correlated. Although the jet mixing noise tends to be the major source at low flight speeds, and the shock noise at high flight speeds, all three sources are comparable in magnitude during the rapid rise-time of the noise signal and at its peak. Indeed, were it possible to reduce greatly both the jet mixing and shock noise, the peak noise levels would only reduce by about 5 dBA. Author

N93-10687# National Physical Lab., Teddington (England).
MEASUREMENT AND PREDICTION OF NOISE FROM LOW-ALTITUDE MILITARY AIRCRAFT OPERATIONS
BERNARD F. BARRY, RICHARD C. PAYNE, ANTHONY L. HARRIS, and RALPH J. WESTON (Royal Air Force, Halton, England), *In* AGARD, Combat Aircraft Noise 13 p (SEE N93-10666) 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

In response to the rapid growth in demand for information on noise levels around military airfields in the UK, NPL developed AIRNOISE, a mathematical model for computing aircraft noise contours. Since its first applications in 1981, the model has been used to determine zones of eligibility within the MoD compensation scheme. The model has been subject to continuous development, e.g., the incorporation of Harrier V/STOL operations. We have now extended the model to include noise from high-speed, low-level operations. The model predicts not only maximum levels but the complete time-history, so that the time-onset rate can be estimated. To aid refinement and validation of the model, a special exercise has been conducted in which Tornado, Harrier, Jaguar, Hawk, F-15 and F-16 aircraft have flown straight and level at heights between about 100 and 400 feet, at various speeds and engine power settings over an array of microphones. This paper describes the trial and the results obtained. The prediction model is outlined and comparisons made between predictions and measurements. Author

N93-10688# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain).
MECHANISMS OF SOUND GENERATION IN SUBSONIC JETS
E. CAMPOS and F. MALLEN *In* AGARD, Combat Aircraft Noise 18 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

This paper gives an overview of some important features of the process of sound generation in subsonic jets. The outstanding aeroacoustic theories are briefly reviewed and some distinguished phenomena relevant to jet noise, like both the effects of source convection and temperature are explained. Finally some mechanisms of sound generation by turbulent jets reported in the literature on the topic are examined. Author

N93-10689# Motoren- und Turbinen-Union Muenchen G.m.b.H., Munich (Germany).
COMBAT AIRCRAFT NOISE REDUCTION BY TECHNICAL MEASURES
M. WEGNER, F. KENNEPOHL, and K. HEINIG *In* AGARD, Combat Aircraft Noise 13 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

The noise of combat aircraft during low level flight is dominated by the jet. Technical noise reduction measures must therefore reduce the specific thrust of the engine. This can be achieved by altering the engine cycle or by using secondary air to increase the mass flow though the nozzle. In the first part the influence of nozzle area, bypass ratio and variable cycle features on the specific thrust of modern fighter engines is shown. The effects on noise, thrust and fuel consumption are discussed. In the second part ejector-mixer nozzles and the aft-fan are considered. Both reduce the jet velocity by entraining air through secondary inlets and expelling it together with the engine's exhaust flow through a common nozzle. Author

N93-10690# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany).
TECHNICAL MEASURES FOR THE ATTENUATION OF AIRCRAFT NOISE AND THEIR APPLICABILITY TO GAF COMBAT AIRCRAFT
H. TOENSKOETTER, S. BLAECK, and R. RICHTER *In* AGARD, Combat Aircraft Noise 8 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A02/MF A03

Possible technical measures for the reduction of aircraft engine noise are evaluated with respect to the noise attenuation potential at take-off, low level flight and landing and their applicability to the combat aircraft of the German Air Force (GAF) is discussed. Based on this analysis short and mid term solutions for Tornado are proposed and investigated with respect to noise attenuation, integration, weight, flight performance, operational impact and safety. The design concept of a 'Low Noise Training-Tornado' with reheatless RB199 engines and ejector nozzles is described. Author

N93-10691# Dornier Luftfahrt G.m.b.H., Friedrichshafen (Germany).
STUDY RESULTS ON COMBAT AIRCRAFT SOURCE NOISE REDUCTION
I. U. BORCHERS, H. J. HACKSTEIN, and P. BARTELS *In* AGARD, Combat Aircraft Noise 24 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A03/MF A03

For use in combat aircraft noise control, important results of extensive studies on jet noise reduction are presented. The studies covered low-noise nozzle designs such as linear arrays of circular nozzles, inverted profile jets as well as special shape mixing nozzles and coaxial bypass flow configurations. In addition interesting results of systematic research on special acoustic absorbers for propulsion system internal noise reduction and of initial theoretical and experimental studies on promising ejector flow systems are reported. The results of the different investigations are explained and discussed. Furthermore, practical applications, including examples of performed and possible future integrations of the considered noise control measures into aircraft, are presented. It is noted that the implementation of these methods could significantly reduce combat aircraft engine noise. For substantial noise reductions, of the order of 20 dB or more as obtained for civil jet transport aircraft, the integration of advanced ejector flow systems is suggested which are capable of effectively lowering the jet exhaust speed as required and with this strongly reduce the jet noise generation. It is concluded that extensive information and an advanced technology basis for jet engine noise reduction exist. Applying this, by giving the needed noise control equal importance and priority as other critical aircraft aspects, may help resolve the related noise problem. Author

N93-10692# Messerschmitt-Boelkow G.m.b.H., Munich (Germany). Aeroacoustics.
REDUCTION OF PROPELLER NOISE BY ACTIVE NOISE CONTROL
O. BSCHORR and D. KUBANKE *In* AGARD, Combat Aircraft Noise 10 p (SEE N93-10666 01-71) Apr. 1992
(AGARD-CP-512) Copyright Avail: CASI HC A02/MF A03

Active noise control, a method of cancelling noise by means of interference with a secondary anti-noise source, is now in full development. The first commercial application of this technique is in the case of active electronically controlled head sets. The next step will be the active noise cancellation in air ducts and in passenger cabins. The aim of this paper is to assess the possibilities of the anti-noise technique for reducing propeller noise. First, by a mathematical simulation the theoretical noise reduction on the ground was calculated and found to be promising for further investigations. In the case of the periodic engine and propeller noise, for example, with only a single anti-noise source, the noise foot prints of the lower propeller harmonics can be reduced by up to 10 dB. In laboratory tests the theoretical values will be confirmed experimentally. For cancellation of the periodic noise one can use synchronous anti-noise generators. Compared with the engine and propeller noise the reduction of jet noise by the anti-noise technique is much more difficult. Therefore a sensor and controlling unit are necessary because of the stochastic nature of jet noise. Since aircraft noise is a severe problem, all methods are to be considered. Author

N94-37280# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Bretigny sur Orge (France).
3D SOUND EXPERIMENTAL APPROACH: METHODOLOGY AND PRELIMINARY RESULTS [APPROCHE EXPERIMENTALE DU SON 3D: METHODOLOGIE ET RESULTATS PRELIMINAIRES]
L. PELLIEUX, C. GULLI, P. LEROYER, B. PLEDECOCQ, ALAIN LEGER, and J. P. MENU *In* AGARD, Virtual Interfaces: Research and Applications 6 p (SEE N94-37261 12-53) May 1994 In FRENCH
(AGARD-CP-541) Copyright Avail: CASI HC A02/MF A02
The principle of 3D sound, its domain of application and the mechanisms used by man to locate sounds are reviewed. The work in progress is described. The goal is to measure human performance in locating a simulated sound source, using a stereophonic helmet. The study is made of two parts: individual measurements on the head's acoustic dispersion characteristics (head transfer functions) on four subjects, and performance testing on finding locations, the subjects listening to sounds issued from their own transfer functions. The subject must aim toward the perceived source as previously as possible, regardless of the length of time needed to respond. The sources are not materialized and the subject is kept in a dark environment. Results show that finding the angle of location is easy for the 4 subjects. On the other hand, finding the site is very difficult for 2 of the subjects. In the case of the best subject, there is an actual 6 degree error in the aim. Author

N95-19142# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
IMPACT OF ACOUSTIC LOADS ON AIRCRAFT STRUCTURES [IMPACT DES SOLICITATIONS ACOUSTIQUES SUR LES STRUCTURES D'AERONEFS]
Sep. 1994 265 p In ENGLISH and FRENCH Symposium held in Lillehammer, Norway, May 1994 Original contains color illustrations
(AGARD-CP-549; ISBN-92-836-0001-0) Copyright Avail: CASI HC A12/MF A03
A broad band of different activities was addressed in the Specialists' Meeting held by the Structures and Materials Panel of AGARD in May 1994: Topics dealt with the acoustic environment in subsonic and hypersonic flow regimes, innovative structural design techniques and materials for fatigue resistant structures, and experimental and analytical tools for evaluation of the behavior of structures in an acoustically and thermally adverse environment. For individual titles, see N95-19143 through N95-19167.

N95-19143# British Aerospace Aircraft Group, Warton (England). Military Aircraft Div.
CURRENT AND FUTURE PROBLEMS IN STRUCTURAL ACOUSTIC FATIGUE
P. D. GREEN *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 5 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A01/MF A03
Acoustic fatigue failures can be caused by the dynamic response of aircraft structures to unsteady pressure loading from aerodynamic and engine acoustic sources. The life of structures is often difficult to assess accurately and may be greatly affected by steady thermal, in-plane and out-of-plane loads. Furthermore, currently available methods do not enable fatigue life assessment of the substructure to be made, despite these failures occurring regularly in service. This paper discusses current problems associated with structural acoustic fatigue and extends upon this to account for likely clearance philosophies and configurations for future aircraft. Author

N95-19144# Eurocopter Deutschland G.m.b.H., Munich (Germany).
HELICOPTER INTERNAL NOISE
G. NIESL and E. LAUDIEN (Daimler-Benz A.G., Munick, Germany.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 12 p (SEE N95-19142 05-71) Sep. 1994 Sponsored in part by BRITE/EURAM
(Contract(s)/Grant(s): PROJ. RHINO)
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03
Compared to fixed wing aircraft, helicopter interior noise is higher, and subjectively more annoying. This is mainly due to discrete frequencies by the main transmission system, and also from other components like main and tail rotor, engines, or cooling fans. Up to now, mainly passive measures have been used for interior noise reduction. Despite intensive experimental and theoretical investigation to improve acoustic treatment, their weight penalties remain high especially in the low frequency range. Here, active noise control offers additional capacities without excessive weight efforts. Loud-speaker based systems are sufficiently well developed for implementing a prototype system in the helicopter. Two other principles are in development: active panel control which introduces mechanical actuators to excite the cabin walls, and active control of gearbox struts with actuators in the load path between gearbox and fuselage. Author

N95-19145# Dassault Aviation, Saint-Cloud (France).
AEROACOUSTIC QUALIFICATION OF HERMES SHINGLES [DIMENSIONNEMENT ET QUALIFICATION AEROACOUSTIQUE DES TUILES HERMES]
C. PETIAU and A. PARET *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 17 p (SEE N95-19142 05-71) Sep. 1994 In ENGLISH and FRENCH
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03
General problems of aeroacoustic analysis are presented, taking as an example shingle studies of the HERMES space shuttle. Analysis of shingle behavior meets this problem in a particularly difficult way (very hard environment, specific difficulties due to design of shingles). Available analysis tools include: (1) calculation means, which are mainly those of aeroelasticity, and (2) ground test means (wind tunnel, progressive wave tubes, shaker,...). None of these means can alone satisfy the needs of structural dimensioning and qualification; in particular the calculation of turbulent sources is not possible today, and they are very difficult to simulate with ground testing of actual structural parts. In spite of these difficulties, and referring to the preliminary tests and calculations of HERMES shingles, a rational strategy is proposed for aeroacoustic dimensioning and qualification of structural parts. This leads to a succession of tests, the conditions of which are determined by calculations, calculation models being themselves validated by comparison with test results. Author

N95-19146# Wright Lab., Wright-Patterson AFB, OH. Structural Dynamics Branch.
WEAPONS BAY ACOUSTIC ENVIRONMENT
L. L. SHAW and R. M. SHIMOVETZ *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 10 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03
An aircraft weapons bay exposed to freestream flow experiences an intense aeroacoustic environment in and around the bay. Experience has taught that the intensity of this environment can be severe enough to result in damage to a store, its internal equipment, or the structure of the weapons bay itself. To ensure that stores and sensitive internal equipment can withstand this hazardous environment and successfully complete the mission, they must be qualified to the most severe sound pressure levels anticipated for the mission. If the qualification test levels are too high, the store and its internal equipment will be over designed, resulting in unnecessary costs and possible performance penalties. If the qualification levels are below those experienced in flight, the store or its internal equipment may catastrophically fail during performance of the mission. Thus, it is desirable that the expected levels in weapons bays be accurately predicted. A large number of research efforts have been directed toward understanding flow-induced cavity oscillations. However, the phenomena are still not adequately understood to allow one to predict the fluctuating pressure levels for various configurations and flow conditions. This is especially true at supersonic flow speeds, where only a small amount of data are available. This paper will give a background of flow induced cavity oscillations and discuss predictions, control and suppression, and the future of weapons bay acoustic environments. A large number of research efforts have been directed toward understanding flow-induced cavity oscillations. However, the phenomena are still not adequately understood to allow one to predict the fluctuating pressure levels for various configurations and flow conditions. This is especially true at supersonic flow speeds, where only a small amount of data are available. This paper will give a background of flow induced cavity

oscillations and discuss predictions, control and suppression, and the future of weapons bay acoustic environments. Author

N95-19147# Alenia, Turin (Italy).
IMPACT OF NOISE ENVIRONMENT ON ENGINE NACELLE DESIGN
R. GIUZIO, E. DALLE-MURA, and G. GIUFFRE *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 11 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03

The present paper describes the general philosophy and the followed methodology in engine nacelle design, usually resulting in the embodiment of acoustic treatment in intake and exhaust ducts to make the relevant aircraft compliant with noise certification requirements. A general description of conventional acoustic liners currently in service, and liners of innovative design currently being investigated is also included, giving emphasis to the methodology for the selection of the proper acoustic treatment. Finally the Alenia software package (ALNOIS), ad hoc developed to cover the complete engine nacelle acoustic design and to support the acoustic panels manufacturing, is briefly described. Author

N95-19148*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
IMPACT OF DYNAMIC LOADS ON PROPULSION INTEGRATION
J. M. SEINER *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 14 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03

Aircraft dynamic loads produced by engine exhaust plumes are examined for a class of military fighter and bomber configurations in model and full scale. The configurations examined are associated with the USAF F-15 and B-1B aircraft, and the US F-18 HARV and ASTOVL programs. The experience gained as a result of these studies is used to formulate a level of understanding concerning this phenomena that could be useful at the preliminary stage of propulsion/airframe design. Author

N95-19149# Wright Lab., Wright-Patterson AFB, OH. Chief, Structural Integrity Branch.
HIGH-TEMPERATURE ACOUSTIC TEST FACILITIES AND METHODS
JEROME PEARSON *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 9 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

The Wright Laboratory is the Air Force center for air vehicles, responsible for developing advanced technology and incorporating it into new flight vehicles and for continuous technological improvement of operational air vehicles. Part of that responsibility is the problem of acoustic fatigue. With the advent of jet aircraft in the 1950's, acoustic fatigue of aircraft structure became a significant problem. In the 1960's the Wright Laboratory constructed the first large acoustic fatigue test facilities in the United States, and the laboratory has been a dominant factor in high-intensity acoustic testing since that time. This paper discusses some of the intense environments encountered by new and planned Air Force flight vehicles, and describes three new acoustic test facilities of the Wright Laboratory designed for testing structures in these dynamic environments. These new test facilities represent the state of the art in high-temperature, high-intensity acoustic testing and random fatigue testing. They will allow the laboratory scientists and engineers to test the new structures and materials required to withstand the severe environments of captive-carry missiles, augmented lift wings and flaps, exhaust structures of stealth aircraft, and hypersonic vehicle structures well into the twenty-first century. Author

N95-19152# Rome Univ. (Italy). Dept. of Aerospace.
ACOUSTICS OF SPACE STRUCTURES
P. SANTINI, F. MORGANTI (Alenia Spazio S.p.A., Rome, Italy.), and R. GIOVANNUCCI *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 13 p (SEE N95-19142 05-71) Sep. 1994
Sponsored in cooperation with the Italian Ministero per la Universita e per la ricerca Scientifica e Technologica
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The problem of the response of a panel belonging to a space structure or to a launcher is considered. By using a modal approach in the frequency domain, the structure is described through a finite element model, and the acoustic field through Green's function. The presence of the air is considered, and it leads to an addition to the mass matrix and to the damping matrix of the relevant terms. The transfer function is then applied to the case of random inputs, for which an analytical expression is provided. Some numerical examples show the effect of the additional terms on the spectral distribution and on the relevant RMS value. Author

N95-19155# Construcciones Aeronauticas S.A., Madrid (Spain). Structural Dynamics Dept.
APPLICATION OF THE PSD TECHNIQUE TO ACOUSTIC FATIGUE STRESS CALCULATIONS IN COMPLEX SUBSTRUCTURES
H. CLIMENT and J. CASALENGUA *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 11 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03

A method for stress calculation using the Power Spectral Density (PSD) technique for acoustic fatigue evaluation is presented. The sound pressure levels (SPL) are converted to acoustic pressures PSD and applied to a finite element model representation of the substructure. This technique can cover: complex geometries in substructures, detailed effects of reinforcements and the contribution of several normal modes, improving the previous procedure based on ESDU data sheets that accounts for simple geometries and only contributions of the first mode are considered. The method is used to predict stresses at substructures subjected to a severe acoustic environment. Comparison with acoustic fatigue test results show good correlation between experimental data and theoretical analyses in terms of stresses and accelerations providing an encouraging basis for further work in this direction. Author

N95-19156# Deutsche Aerospace A.G., Bremen (Germany).
ACOUSTIC FATIGUE TESTING ON DIFFERENT MATERIALS AND SKIN-STRINGER ELEMENTS
KLAUS KOENIG *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 11 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03

Within a comparative study, 29 different coupons covering 8 different designs and 6 different materials were fatigued by an excitation of 30 g(exp 2)/Hz on a shaker. The selected designs and materials represent realistic alternatives of an aircraft surface structure. The investigation led to the following conclusion: (1) Besides classical aluminium, CFRP is the best material with regard to sonic fatigue. (2) Al/Li, ARALL and Al layer materials showed shorter life times than the classical Al. (3) The most striking improvement in design for the dimensions selected here was achieved with separate doublers between skin and stringer. (4) The modal damping found was most often smaller than the 1.7 percent of the critical as known from ESDU for Al. (5) Pure CFRP without rivets showed the smallest damping: 0.6 - 0.9 percent. Author

N95-19157# McDonnell-Douglas Corp., Saint Louis, MO.
ACOUSTIC FATIGUE CHARACTERISTICS OF ADVANCED MATERIALS AND STRUCTURES
J. H. JACOBS and M. A. FERMAN (Saint Louis Univ., Cahokia, IL.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 9 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

A summary of McDonnell Douglas Aerospace's (MDA) capability for treating acoustic loading on modern fighter aircraft structure is given. A brief overview of techniques that have been developed since the mid-70's are presented. In metallic structure fabrication concepts such as Super Plastic Formed/Diffusion Bonding (SPF/DB) suddenly required new analysis procedures. In addition, the 1980's brought the additional complications of structures exposed to high thermal and acoustic environments on such vehicles as the AV-8V Harrier II and National Aerospace Plane (NASP). Methods developed to handle these new material forms, intense noise, and thermal loads are discussed. The influences of nonlinear structural responses on fatigue life due to combined load environments are also discussed. Additional developments in thermal-acoustic testing capability are also discussed. Author

N95-19158# Daimler-Benz A.G., Munick (Germany).
ACOUSTIC FATIGUE OF CARBON FIBRE STRUCTURES
G. MUELLER and M. GRUENEWALD *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 7 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

Based on the acoustic fatigue endurance curve of CFRP-probes (Carbon Fibre Reinforced Plastic) obtained within the BRITE EURAM PROGRAMME - ACOUFAT further investigations have been carried out with respect to (1) nonlinearities in the measurements for the calibration of the different transducers; (2) effects of residual strength for the coupons; (3) effects of moisture and temperature in the material due to storage and testing in humid environment. For one chosen coupon type, the sum of these effects leads to a reduction of the allowable strain in the range of high cycles by a factor of approximately 4 compared to the value obtained originally for the coupon using the 2 percent failure criterion and tested at room temperature. The modifications are considered step by step and the resulting curve is given in this paper. Author

N95-19159# Dassault Aviation, Saint-Cloud (France). Structures Div.
BRITE-EURAM PROGRAMME: ACOUFAT ACOUSTIC FATIGUE AND RELATED DAMAGE TOLERANCE OF ADVANCED COMPOSITE AND METALLIC STRUCTURES
D. TOUGARD *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 12 p (SEE N95-19142 05-71) Sep. 1994 Sponsored in cooperation with the European Community and ACOUFAT
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03

The Brite/Euram programme ACOUFAT is concerned with 'Acoustic fatigue and related damage tolerance of advanced composite and metallic structure'. Three main fields of the ACOUFAT results are discussed: (1) The use of a 'frequency degradation' criterion, usually applied to classical metallic materials and early Carbon Fiber Reinforced Plastic (CFRP) materials, is not considered suitable, as the only parameter, for determination of CFRP specimen 'failure' in acoustic fatigue. It is suggested that a suitable criterion should be based, in further work, upon the degradation of the mechanical properties of the specimens; (2) On the basis of Wind-Tunnel (WT) calibration tests, a semi-empirical model of the spatio-temporal characteristics of the aero-acoustic loads exerted on a flat panel by the turbulent field created by a flap has been developed and utilized as 'Load Data Input' for Finite Element (FE) calculations. The WT tests have been reasonably well presented: the development of this semi-empirical model is an encouraging initial success. The results from the initial modelling suggest that this can be extended to the modelling of the acoustic loads in Progressive Wave Tubes (PWT); and (3) The excitation of structures by aero-acoustic loads may not be simulated fully in PWT by simply modifying and correctly shaping the spectral content. The effect of the spatial distribution of the loading is clearly different in both cases and the tested specimen endurance may be significantly different. It is clear that a theoretical approach based on a correct prediction of the responses to both types of environment is required. Author

N95-19160# Fokker B.V., Schipol-Oost (Netherlands).
ACOUSTIC FATIGUE BEHAVIOUR OF GLARE COMPOSITES
P. T. ELANGOVAN, H. OTTENS (National Aerospace Lab., Marknesse, Netherlands.), and G. BAYERDORFER (Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn, Germany.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 8 p (SEE N95-19142 05-71) Sep. 1994 Sponsored in part by ACOUFAT
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The GLARE (Glass Aluminum Reinforced) laminates, a new type of fiber metal laminates with promising fatigue behavior, are evaluated for their acoustic fatigue properties. In this investigation, the endurance data are developed by using shaker test specimens. Since the GLARE laminates make use of lay-ups and metal bonding, the influence of the laminate lay-up configuration and temperature on the acoustic fatigue strength is investigated from the shaker test results. Four types of shaker specimens are used in this investigation: plain cantilever, riveted skin-stringer, bonded skin-stringer, and rib-mode vibration specimens. Two stiffened GLARE skin panels are tested in the Progressive Wave Tube (PWT) at IABG. The panel testing indicates the importance of the secondary structure in the acoustic environment, although the GLARE skin itself does not show any damage. Author (revised)

N95-19162# British Aerospace Aircraft Group, Bristol (England).
APPLICATION OF SUPERPLASTICALLY FORMED AND DIFFUSION BONDED STRUCTURES IN HIGH INTENSITY NOISE ENVIRONMENTS
R. J. CUMMINS and J. P. C. WONG *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 10 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

Two specimens, representing an aircraft control surface and an access door, have been tested under high intensity acoustic excitation. The access door was also subjected to an elevated temperature environment of 150 C during this test. These specimens were manufactured as multi-cell box configurations by superplastic forming and diffusion bonding (SPFDB) to a similar structural weight as existing aircraft components produced by alternative means of construction. The influence of the spandrel-shaped void, formed at the skin/stringer intersection, on the acoustic fatigue performance is considered. Author (revised)

N95-19163# Alenia Spazio S.p.A., Turin (Italy).
AN OVERALL APPROACH OF COCKPIT NOISE VERIFICATION IN A MILITARY AIRCRAFT
R. GIUZIO and M. NORESE (Aeronautica Macchi S.p.A., Varese, Italy.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 12 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03

The present paper describes the applicable concepts for cockpit noise verification in military aircraft. A design-to-noise procedure is outlined and the overall requirements for medical, intelligibility and operational aspects are discussed, including the proposition of an adequate index to quantify the quality of noise at the pilot's ear. Guidelines for cockpit noise control, to be applied during the design phase of the project, are given together with the expected benefits. Advanced noise control measures and noise measuring techniques are also dealt with and a specific case of cockpit noise verification is described. Author (revised)

N95-19164# National Research Council of Canada, Ottawa (Ontario). Inst. for Aerospace Research.
NOISE TRANSMISSION AND REDUCTION IN TURBOPROP AIRCRAFT
DOUGLAS G. MACMARTIN, GORDON L. BASSO, and BARRY LEIGH (De Havilland Aircraft Co. of Canada Ltd., Downsview, Ontario.) *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 9 p (SEE N95-19142 05-71) Sep. 1994
(AGARD-CP-549) Copyright Avail: CASI HC A02/MF A03

There is considerable interest in reducing the cabin noise environment in turboprop aircraft. Various approaches have been considered at deHaviland Inc., including passive tuned-vibration absorbers, speaker-based noise cancellation, and structural vibration control of the fuselage. These approaches will be discussed briefly. In addition to controlling the noise, a method of predicting the internal noise is required both to evaluate potential noise reduction approaches, and to validate analytical design models. Instead of costly flight tests, or carrying out a ground simulation of the propeller pressure field, a much simpler reciprocal technique can be used. A capacitive scanner is used to measure the fuselage vibration response on a deHaviland Dash-8 fuselage, due to an internal noise source. The approach is validated by comparing this reciprocal noise transmission measurement with the direct measurement. The fuselage noise transmission information is then combined with computer predictions of the propeller pressure field data to predict the internal noise at two points. Author

N95-19166# LMS International, Leuven (Belgium).
IDENTIFICATION AND ANALYSIS OF AIR- AND STRUCTURE-BORNE NOISE AND VIBRATION PATHS
HERMAN VANDERAUWERAER, KATRIEN WYCKAERT, and PETER VANDERLINDEN *In* AGARD, Impact of Acoustic Loads on Aircraft Structures 11 p (SEE N95-19142 05-71) Sep. 1994 Sponsored in cooperation with the European Commission
(AGARD-CP-549) Copyright Avail: CASI HC A03/MF A03

In order to investigate the contribution of individual sources and source transmission paths, a method referred to as 'Transfer

Path Analysis' has been developed. Its formulation to address structure-born noise problems is outlined in detail and illustrated with an example from the car industry. Current research in this context is briefly reviewed, including the case of reciprocity techniques and the air-born noise problem. Author

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OPTICS

Includes light phenomena; and optical devices.

N92-28088# Rome Univ. (Italy). Dipartimento di Fisica.
NONLINEAR EFFECTS IN OPTICAL FIBERS
BRUNO CROSIGNANI *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 20 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A03/MF A02
The basic differential equations necessary to represent nonlinear propagation of short and ultrashort optical pulses in dielectric waveguides are derived. After introducing fundamental and high-order soliton solutions of the nonlinear Schroedinger equations, the possibilities of realizing soliton-based communication systems are discussed. Higher order nonlinear effects associated with self-Raman gain and optical amplification in connection with the use of active fibers are also described. Author

N92-28089# Southampton Univ. (England). Optoelectronics Research Centre.
ACTIVE FIBRES AND OPTICAL AMPLIFIERS
DAVID N. PAYNE *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 26 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A03/MF A02
The incorporation of rare earth ions into glass fibers to form fiber lasers and amplifiers is not a recent development. However, the fiber laser is only now beginning to receive widespread attention as a possible contender for a well controlled, stable light source for telecommunications, lidar, sensors, and meteorology, despite its obvious advantages of high power pulse operation, single frequency capability, ease of access to the resonator, and compatibility with communications fibers. Much of the current interest stems from the unique ability of the fiber laser to generate high purity soliton pulses of a few picoseconds in duration for potential application in the soliton-based, long haul high capacity communications links of the future. H.A.

N92-28090# McDonnell-Douglas Electronic Systems Co., Santa Ana, CA.
OPTICAL FIBER SENSORS
ERIC UDD *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 18 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A03/MF A02
Fiber optic sensors are finding increased usage in aerospace guidance and control applications due to their light weight, immunity to electromagnetic interference, high bandwidth and sensitivity, and solid-state, all passive nature. This paper reviews fiber optic sensors with particular emphasis on aerospace applications. Author

N92-28091# Strathclyde Univ., Glasgow (Scotland). Smart Structures Research Inst.
SMART STRUCTURES: THE RELEVANCE OF FIBRE OPTICS
BRIAN CULSHAW and PETER T. GARDINER *In* AGARD, Advances in Fibre-Optic Technology in Communications and for Guidance and Control 17 p (SEE N92-28084 18-32) May 1992
(AGARD-LS-184) Copyright Avail: CASI HC A03/MF A02
The concept of smart structures integrates structural engineering, sensing, control systems, and actuation to provide a mechanical assembly which is capable of responding to its environment and/or loading conditions. The realization of the smart structure requires integration of skills in a variety of scientific and engineering disciplines ranging from mechanical engineering through materials science into signal processing, data analysis, sensing, and actuation. The sensing technology must have a number of key features of which the ability to take distributed measurements of various parameters throughout the structure is paramount. Fiber optics technology therefore promises to have a significant role to play in the evolution of smart structures concepts. This paper analyzes this role in detail, presents an assessment of the current state-of-the-art in fiber optic technology related to smart structures and presents a scenario for future developments. Author

N92-32441# Naval Weapons Center, China Lake, CA. Attack Weapons Dept.
IMAGE ENHANCEMENT OF INFRARED UNCOOLED FOCAL PLANE ARRAY IMAGERY
HOWARD MCCAULEY and JOHN ERIC AUBORN *In* AGARD, Integrated Target Acquisition and Fire Control Systems 4 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A01/MF A02; 1 functional color page
Several simple, low-cost algorithms were explored for use in the enhancement of imagery produced by uncooled focal plane arrays (UFPA). These algorithms address the main problems that UFPA-produced imagery typically demonstrate. In addition to enhancing UFPA-produced imagery, all of the algorithms are simple and allow for inexpensive hardware implementation. Author

N92-32444# Thomson-CSF, Cesson-Sevigne (France).
METHODS OF OPTO-ELECTRONIC FUSION OF INFRARED AND VISIBLE IMAGES [METHODES DE FUSION OPTRONIQUE D'IMAGES IR ET VISIBLE]
D. THOREAU and J. QUIGNON (Thomson-CSF, Bagneux, France), *In* AGARD, Integrated Target Acquisition and Fire Control Systems 8 p (SEE N92-32437 23-06) Feb. 1992 In FRENCH Original contains color illustrations
(AGARD-CP-500) Copyright Avail: CASI HC A02/MF A02; 1 functional color page
The interpretation of images could be greatly facilitated by simultaneously considering the images of the same scene produced by captors of different types. Thus, a global approach to the problem of opto-electronic fusion between two captors, infrared (IR) and visible, is arrived at here, with three levels of association of data. The fusion of data can be made at the decision making level (class of objects), at the intermediary level (elementary objects), and finally at the level that the signal is issued directly to the captors. At each step of fusion, the problem of the placement in the correspondence of the IR and visible data is posed. This alignment must be as much or more precise as the level of data. The preliminary phase of treatment strongly affects the fusion step. The rules of fusion are developed in such a way as to improve the power of classification, augmenting the probability of detection, utilizing the eventual complementarity of the captors, and permitting a simultaneous visualization of pertinent IR and visible information to the operator. Author

N92-32445# Thomson-CSF, Bagneux (France). Div. Systemes Electroniques.
AUTOMATIC DETECTION, PURSUIT, AND CLASSIFICATION IN INFRARED IMAGERY [DETECTION, POURSUITE ET CLASSIFICATION AUTOMATIQUES EN IMAGERIE INFRA-ROUGE]
J. QUIGNON *In* AGARD, Integrated Target Acquisition and Fire Control Systems 6 p (SEE N92-32437 23-06) Feb. 1992 In FRENCH
(AGARD-CP-500) Copyright Avail: CASI HC A02/MF A02; 1 functional color page
Presented here are certain aspects of the treatment techniques of images and the reconnaissance of forms for automatic detection of targets in infrared imagery. The algorithms described here are put to work in real time for plane, helicopter, and missile targets in view of their integration into the solar defense system. Nevertheless, the algorithms are sufficiently general to be applied to optoelectronic equipment in air to ground and air to air systems. The treatments are of two categories. The first category includes those which are carried over the reduced zones of the entire field analyzed by the sensor (typically, 2 degrees by 3 degrees for a thermal camera from a short range arms system). These systems extract from the background potential targets (called alarms). The criteria of segmentation are based on the contrast and the movement of targets in relation to the background. The second

category includes those which are carried over the reduced zones of an image (pursuit window) and which have as a goal the classification (recognition) of potential targets and their pursuit.
Author

N92-32446# Wright Lab., Wright-Patterson AFB, OH.
INFRARED TARGETING SYSTEM (IRTS) DEMONSTRATION
MARK A. OHAIR, SHELLY S. EUCKER (Boeing Military Airplane Development, Wichita, KS.), BRAD A. EUCKER (Boeing Military Airplane Development, Wichita, KS.), and TIM LEWIS *In* AGARD, Integrated Target Acquisition and Fire Control Systems 6 p (SEE N92-32437 23-06) Feb. 1992
(AGARD-CP-500) Copyright Avail: CASI HC A02/MF A02; 1 functional color page

The objective of the Infrared Targeting System (IRTS) is to successfully demonstrate the mission performance that can be achieved in manned air-to-ground targeting applications utilizing a synergistic combination of state of the art active/passive infrared sensor and automatic target recognizer (ATR) technologies. The IRTS program is centered around a demonstration FLIR/Laser Radar/ATR (FLASHER). The FLASHER consists of a dual field of view (2 x 2 degree and 6 x 6 degree) second generation FLIR pixel mapped to a CO2 laser radar, with a FLIR ATR processor, a laser radar ATR processor, and a sensor fusion ATR processor. Following construction and laboratory testing of the IRTS, the system will be installed on a test aircraft and demonstrated in flight against realistic tactical, strategic, and special operations scenarios.
Author

N93-22020# British Aerospace Systems and Equipment Ltd., Plymouth (England).
ADVANCES IN AUTOMATIC ELECTRO-OPTICAL TRACKING SYSTEMS
ANTHONY J. E. MOY and ANDREW D. HUGHES *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 12 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A03/MF A02

British Aerospace (Systems & Equipment) Ltd (BASE) has been working in the field of automatic electro-optical tracking (Autotrack) systems for more than 12 years. BASE Autotrack systems carry out the automatic detection, tracking and classification of missiles and targets using image processing techniques operating on data received from electro-optical sensors. Typical systems also produce control data to move the sensor platform, enabling moving targets to be tracked accurately over a wide range of conditions. BASE Autotrack systems have been well proven in land, sea and air applications. This paper discusses the relevance of Autotrack systems to modern high-technology warfare and charts the progress of their development within BASE, both with respect to current products and active research programs. Two third generation BASE Autotrack systems are described, one of which provided a sophisticated air-to-ground tracking capability in the recent Gulf War. The latest Autotrack product is also described; this uses ASIC and Transputer technology to provide a high-performance, compact, missile and target tracker. Reference is also made to BASE's research work. Topics include an ASIC correlator, point target detection and, in particular, the use of neural networks for real-time target classification.
Author

N93-22025# Prins Maurits Lab. TNO, Rijswijk (Netherlands).
SYSTEM EVALUATION OF A FIBER OPTIC GUIDED MISSILE WITH A SIMPLE GUIDANCE ADDITION TO IMPROVE SYSTEM EFFECTIVENESS
A. J. KRABBENDAM *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 12 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A03/MF A02

Based on lessons learned during the accomplishment of a National Technology Project in the Netherlands, a simple and low cost Fiber Optic Guided Weapon (FOGW) concept was contrived. The main characteristics of the concept are the short range of 10 km, the simple strapdown television CCD-camera, and the solid fuel rocket propulsion. This low cost concept is more closely examined. The concept was evaluated by conducting flight trajectory simulations. An already existing six degrees of freedom (6-DOF) trajectory simulation program was modified. The program and especially the relatively simple target sensor system model are described. The problem of choosing an appropriate target configuration for system evaluation is attended to. A target configuration consists of various target positions, various target maneuvers, and various target speeds. The probability of hit is calculated for a chosen target configuration base-case. Miscellaneous model parameters are varied, especially the target sensor system is investigated. The probability of hit is determined as a function of the sensor resolution, the sensor field of view, and the modeled characteristics of the image processing algorithm. Another investigation concerns a simple addition to the normal guidance commands trying to reduce target-lost situations. The effect of two different implementations of this addition is calculated for the same situation as the basic guidance configuration.
Author (revised)

N93-22026# Naval Air Warfare Center, China Lake, CA. Weapons Div.
LINEAR PAYOUT SYSTEMS FOR DISPENSING FIBER-OPTIC DATA LINKS FROM PRECISION-GUIDED MUNITIONS OR HIGH-PERFORMANCE AIRCRAFT/MISSLES
F. HOBAN and D. HARMS *In* AGARD, Advances in Guidance and Control of Precision Guided Weapons 5 p (SEE N93-22018 08-31) Nov. 1992
(AGARD-CP-524) Copyright Avail: CASI HC A01/MF A02

Theoretical studies and empirical tests were conducted as part of the development and demonstration of a fiber-optic data link for weapon system guidance and control. These studies characterized the performance capability of several unique payout system concepts that permit the dispensing of a small diameter (170- to 250-micrometer) fiber-optic data link from military weapon systems at high subsonic velocities. Theoretical predictions were compared with laboratory payout test results. Several engineering models that allow linear dispensing of the fiber from a fiber canister or spool were developed and tested. Material, mechanical, and physical concepts evaluated included spiral flow of air through a payout nozzle, rotating nozzles with fixed geometries, fiber adhesives, and mechanical vibrations. Fiber real-time payout tension loads were measured for several fiber diameters and adhesives. Excellent results were obtained with a silicon-based adhesive with a low coefficient of friction and a 170-micrometer-diameter fiber. The prototype tests verified the results predicted by the theoretical string dynamical models.
Author

N94-10437# MetroLaser, Irvine, CA.
FLOW VISUALIZATION AND SPECTROSCOPY IN HYPERSONIC FLOWS: NEW TRENDS
JAMES TROLINGER, GEORG EITELBERG (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany.), and MARC RAPUC (Avions Marcel Dassault, Saint-Cloud, France.) *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 11 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

This paper is based upon a session of the NATO Advanced Research Workshop, New Trends in Instrumentation for Hypersonic Research held at the ONERA La Fauga Facility in France during the week of 27 Apr. 1992. The discussion includes some of the frontiers of the technology of flow visualization and spectroscopy as well as a discussion of the current development needs and trends. Included in the discussion are optical integrated measurements such as resonance absorption, schlieren, interferometry, and holographic methods. The discussion shows that while the technology is mature in a broad sense, a significant number of new development areas exist such as resonant holography and phase shifting holographic interferometry. The maturity of the technology makes it immediately applicable to many problems and the untapped potential offers considerable room for improvement of existing capability. The methods which are described can be used in harsh environments and have the potential for becoming flight test diagnostics for the measurement of temperature, density, constituency, and velocity.
Author (revised)

N94-30502# Physics and Electronics Lab. TNO, The Hague (Netherlands).
EXPERIMENTAL EVALUATION OF CAMOUFLAGE EFFECTIVENESS IN THE THERMAL INFRARED
PIETER A. M. JACOBS *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 12 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A03/MF A03

The detectability of a target in the infrared spectral region is determined by differences between the radiative signatures of the target and the local background. This implies that both, the difference in surface temperature and emissivity Delta T resp. Delta epsilon and the distribution of these differences over the target area and the background, are of major importance. Therefore camouflage measures have to address both issues in order to achieve maximum signature adaptation to the background. To determine the ability of a camouflage material to follow temperature changes in the background, measurements of camouflage and background temperatures have to be performed under a variety of meteorological conditions. Measurements of representative weather and background conditions are needed to determine those situations, where the camouflage material effectively reduces the target signature. The degree of temperature reduction depends on the required level of protection, that is for detection, recognition and identification. Statistical analyses are given for various camouflage materials in relation to a number of background elements. Camouflage effectiveness is expressed in the percentage of time for which the apparent temperature contrast between the camouflage material and a background element is 1, 2 or 5 C. Analyses are performed for five consecutive weeks of measurements in summer and winter, using data which were taken during a measurement campaign at Gilze Rijen air force base in 1990. Author

N94-30504# Belgian Army, Peutie (Belgium).
GLOBAL APPROACH TOWARDS THE EVALUATION OF THERMAL INFRARED COUNTERMEASURES
PATRICK VERLINDE and PHILIPPE WILMS *In* AGARD, Atmospheric Propagation Effects Through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation 8 p (SEE N94-30495 08-32) Nov. 1993
(AGARD-CP-542) Copyright Avail: CASI HC A02/MF A03

This paper proposes a procedure for the numerical evaluation of the efficiency of countermeasures in the thermal infrared. This procedure consists of three phases. In the first phase the characteristics of different thermal camouflage materials are tested on a lab-scale. These tests comprise measurements of the attenuation of the incident infrared energy and/or of the thermal emissivity factor. With respect to the attenuation measurement, a calibrated infrared sensor is used, to determine the radiation patterns of an object. The comparison of these patterns before and after the application of a camouflage system, gives an absolute measure of its attenuation. The result of this measurement is important since the attenuation is closely related to the contrast between the camouflaged object and its background and thus to the probability of detection. Contrast however, is not the only important feature for the detection of an object in a thermal image. That is why in a second phase the countermeasures under evaluation are tested in a real environment. During this phase, a numerical value is given to the efficiency of the considered camouflage in the thermal infrared, using features selected from those which are known to be important for human vision. These include, besides contrast, other features such as correlation and texture. The third and final phase aims at a verification and a validation of the test results. Indeed, it is of crucial importance to find a link between the performance obtained in the field and the characteristics measured on a lab-scale. It is also necessary to verify that a good correlation exists between the efficiency as determined by human observers and the result of this numerical evaluation procedure. This will be done using a database of thermal images taken with a GEC Avionics TICM II (8 to 12 micron). Those images are then presented as well to human observers as to the machine in a project called 'Psychotest'. Author

N94-36622# GEC-Marconi Avionics Ltd., Basilon, Essex (England).
INFRARED SEARCH AND TRACK DEMONSTRATOR PROGRAMME
W. D. MCGINN, C. J. TUCKER, and S. NALLANTHIGHAL *In* AGARD, Pointing and Tracking Systems 10 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A02/MF A02

The objective of the infrared search and track (IRST) program is to develop demonstration hardware which will be capable of long range detection and tracking of air targets in an airborne environment. This paper describes each of the major subsystems of the IRST equipment, which comprises the pointing system, the thermal imaging systems and the signal processing system. The various modes of operation are outlined which provide the capability to search for, detect and track multiple targets; to display imagery of a selected target and to provide passive ranging information. The equipment will be flown in an experimental Tornado aircraft and the installation and proposed trials are also described. A description of the ground proving equipment is also included. Author

N94-36625# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
INERTIAL PSEUDO STAR REFERENCE UNIT
MICHAEL F. LUNIEWICZ, DALE T. WOODBURY, JEROLD P. GILMORE, and TZE T. CHIEN *In* AGARD, Pointing and Tracking Systems 14 p (SEE N94-36616 12-18) May 1994
(AGARD-CP-539) Copyright Avail: CASI HC A03/MF A02

Advanced space systems for earth observation sensing and defense applications share a common objective: high-resolution monitoring. They require subsystems that accurately provide precise line-of-sight (LOS) pointing of the monitoring sensor with extreme jitter suppression and a precision attitude control system. To address this objective, Draper has developed a pointing system, the Inertial Pseudo Star Reference Unit (IPSRU). The IPSRU effort is a DARPA and SDI sponsored program at Draper under contract with the USAF Phillips Laboratory. The IPSRU implements a collimated light source mounted on a wide-band, extremely low-noise inertially stabilized platform. The collimated light beam becomes, in effect, a jitter-stabilized pseudo star. In addition, its direction in inertial space can be pointed at a precise rate by commands applied to the platform. Derived from text

N95-14449# Grumman Aerospace Corp., Bethpage, NY.
MISSILE INFRARED RADIATION ANALYSIS
MICHEL ENGELHARDT *In* AGARD, Missile Aerodynamics 27 p (SEE N95-14445 03-02) Jun. 1994
(AGARD-R-804) Copyright Avail: CASI HC A03/MF A03

Modern trends in electro-optical/infrared (E-O/IR) technology for use in missile detection is presented as part of the NATO Advisory Group for Aerospace Research and Development (AGARD) special course on 'Missile Aerodynamics.' The course focuses on the operations of E-O/IR systems. The functions of the components of an E-O/IR system are summarized along with the missile source, background, contrast, and IR detection range equation. Author

N95-19253# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
PARTICLE IMAGE VELOCIMETRY: PRINCIPLES, CURRENT APPLICATIONS AND FUTURE PROSPECTS
M. L. RIETHMULLER *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 12 p (SEE N95-19251 05-34) Jul. 1994
(AGARD-CP-535) Copyright Avail: CASI HC A03/MF A04

The basic principle of the technique of Particle Image Velocimetry is presented. The different methods available are discussed and advantages of each of them are exposed. The latest fully optical processing methods are compared to recent video based techniques. The extension of the measurements technique to 3D and the suppression of the directional ambiguity are presented. Examples of application in a variety of domains are discussed. Author

N95-19274# Central Aerohydrodynamics Inst., Zhukovsky (Russia).
OPTICAL SURFACE PRESSURE MEASUREMENTS: ACCURACY AND APPLICATION FIELD EVALUATION
A. BUKOV, V. MOSHAROV, A. ORLOV, V. PESETSKY, V. RADCHENKO, S. PHONOV, S. MATYASH, M. KUZMIN (Moscow M. V. Lomonosov Inst. of the Technology of Fine Chemicals, USSR.), and N. SADOVSKII (Moscow M. V. Lomonosov Inst. of the Technology of Fine Chemicals, USSR.) *In* AGARD, Wall Interference, Support Interference and Flow Field Measurements 9 p (SEE N95-19251 05-34) Jul. 1994
(AGARD-CP-535) Copyright Avail: CASI HC A02/MF A04

Optical pressure measurement (OPM) is a new pressure measurement method rapidly developed in several aerodynamic research centers: TsAGI (Russia), Boeing, NASA, McDonnell Douglas (all USA), and DLR (Germany). Present level of OPM-method provides its practice as standard experimental method of aerodynamic investigations in definite application fields. Applications of OPM-method are determined mainly by its accuracy. The accuracy of OPM-method is determined by the errors of three following groups: (1) errors of the luminescent pressure sensor (LPS) itself, such as uncompensated temperature influence, photo degradation, temperature and pressure hysteresis, variation of the LPS parameters from point to point on the model surface, etc.; (2) errors of the measurement system, such as noise of the photodetector, nonlinearity and nonuniformity of the photodetector, time and temperature offsets, etc.; and (3) methodological errors, owing to displacement and deformation of the model in an airflow, a contamination of the model surface, scattering of the excitation and luminescent light from the model surface and test section walls, etc. OPM-method allows getting total error of measured pressure not less than 1 percent. This accuracy is enough to visualize the pressure field and allows determining total and distributed aerodynamic loads and solving some problems of local aerodynamic investigations at transonic and supersonic velocities. OPM is less effective at low subsonic velocities (M less than 0.4), and for precise measurements, for example, an airfoil optimization. Current limitations of the OPM-method are discussed on an example of the surface pressure measurements and calculations of the integral loads on the wings of canard-aircraft model. The pressure measurement system and data reduction methods used on these tests are also described. Author

N95-20652# Deutsche Aerospace A.G., Munich (Germany). Military Aircraft Div.
OPTICAL BACKPLANE FOR MODULAR AVIONICS
R. BOGENBERGER and O. KRUMPHOLZ *In* AGARD, Advanced Packaging Concepts for Digital Avionics 6 p (SEE N95-20631 06-06) Oct. 1994
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

An experimental study was carried out by DASA and Daimler Benz Research to demonstrate the feasibility of fiber optic technology for use in Modular Avionics. In the first step of the study an inter module communication up to 16 subscribers, with interconnection length of about 1 m was demonstrated. Backplanes being composed of multimode and monomode fibers were tested in a configuration of 4 parallel data channels, each running with 1 GBit/s. This paper will resume results of investigations as: power budget, influence of modal noise with multimode fibers, effects of feedback, as well as optical interference caused by reflections. The paper then goes on to describe the transparency for given protocols (e.g., PI-bus). A prospect of problems arising of optical interconnections of a relatively large number of subscribers and possible solutions by using in-line amplifiers (optically) are reviewed. The backplane implementation is prepared to be arranged as a serial/parallel bus or a part of a switched network. Finally, this paper will give a synopsis of optical backplane solutions. Author

N95-20654# Bell Telephone Labs., Inc., Whippany, NJ.
THE ROC OPTICAL CONNECTOR
RICHARD J. PIMPINELLA and J. DENNIS SEALS *In* AGARD, Advanced Packaging Concepts for Digital Avionics 6 p (SEE N95-20631 06-06) Oct. 1994
(Contract(s)/Grant(s): F33615-89-C-1036)
(AGARD-CP-562) Copyright Avail: CASI HC A02/MF A03

The new multimode connector has been developed that will function under harsh environmental conditions. It meets the military's need for a reliable optical insert that can be integrated into existing electrical, card-edge connectors. Expanded-beam optics and micro-machined silicon sub-assemblies are employed to achieve low optical loss (less than 1 dB) under blind-mate conditions. Low-mass, floating termini and kinematic design make the ROC connector insensitive to high levels of shock and vibration. Self sealing doors protect the optical assemblies from particulate contamination and abusive handling. The connector has performed flawlessly under extensive environmental and durability testing. This paper will describe the ROC design, features, and test results. Author

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THERMODYNAMICS AND STATISTICAL PHYSICS

Includes quantum mechanics; theoretical physics; and Bose and Fermi statistics.

N94-10448# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Propulsion and Aerothermodynamics Div.
THERMODYNAMIC MODEL OF AIR IN CHEMICAL EQUILIBRIUM
D. GIORDANO and L. MARRAFFA *In* AGARD, Theoretical and Experimental Methods in Hypersonic Flows 15 p (SEE N94-10421 01-02) Apr. 1993
(AGARD-CP-514) Copyright Avail: CASI HC A03/MF A04

A thermodynamic model of air in chemical equilibrium is described. The model includes 13 chemical components, namely N, O, Ar, e(-), NO, N2, 02, N(+), 0(+), Ar(+), NO(+), N2(+), O2(+), and is treated as a mixture of perfect gases. The constant pressure specific heats of the components constitute the basic information to be provided and they are assumed to be specified in the form of interpolating polynomials valid in assigned subranges of a given temperature range; the polynomial expressions were structured to preserve generality and flexibility with respect to temperature range subdivisions and polynomial coefficient data published by various sources. The set of the chemical reactions includes 47 reactions, of which only 9 are independent. The equilibrium composition is solved, in terms either of mass fractions or molar fractions, according to the method of the equilibrium constants and numerically computed by an iterative scheme which proves fast and accurate. A FORTRAN program was written to perform the numerical calculations of the thermodynamic properties and of the equilibrium composition. Temperature range subdivisions and polynomial coefficient data can be implemented at will. Presently, the program includes data from 3 US sources and 1 Soviet source. Discrepancies in the constant pressure specific heats of the components deriving from the choice of different data sources are put in evidence. The process to validate the program is described and validation evidence is given in the relevant diagrams. Author (revised)

N94-18236# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
NON LINEAR DYNAMICS AND CHAOS [LA DYNAMIQUE NON-LINEAIRE ET LE CHAOS]
Jun. 1993 191 p Lecture series held in Stanford, CA and Sophia Antipolis, France, Jun. 1993
(AGARD-LS-191; ISBN-92-835-0714-2) Copyright Avail: CASI HC A09/MF A02

Many efforts were oriented towards the understanding of the unexpected behavior of systems - linear or non-linear. These could be large (weather systems, biological life) or small (automatic pilot). A new branch of dynamics is now considered; it is called 'chaos'. Some general theories emerged and reconsideration of concepts of non-linear control to determine the stability of such systems is now intensively studied in the scientific community. The following topics are covered: linear (including time varying coefficients equations) vs non-linear systems; types of non-linearity; curved characteristics, jumps, bifurcation; nonlinear dynamics; sensibility to initial conditions and/or uncertainties on the system parameters; robustness; neuronal-type machines; chaos - random process behavior; reversibility; irreversibility; Newtonian mechanics and

thermodynamics; fractals; and applications. For individual titles, see N94-18237 through N94-18241.

N94-18237# Nice Univ. (France). Inst. Non-Lineaire.
BIFURCATION THEORY: CHAOS AND PATTERNS
P. COULLET *In* AGARD, Non Linear Dynamics and Chaos 13 p (SEE N94-18236 04-77) Jun. 1993 Sponsored by CNRS and Commission of the European Communities
(AGARD-LS-191) Copyright Avail: CASI HC A03/MF A02

The transition towards chaos through the cascade of period doubling bifurcations and the phenomena of symmetry breaking and pattern formation are studied. The qualitative and universal aspects of these phenomena are emphasized. Author (revised)

N94-18238# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
STABILITY ANALYSIS THROUGH BIFURCATION THEORY, 1
P. GUICHETEAU *In* AGARD, Non Linear Dynamics and Chaos 10 p (SEE N94-18236 04-77) Jun. 1993
(AGARD-LS-191) Copyright Avail: CASI HC A02/MF A02

This communication is the first part of the three papers which are presented by the author in the same AGARD Lecture Series (LS 191). It aims at the study of asymptotic solutions of non-linear differential equations depending on parameters. The first part is devoted to a brief presentation of the basis of Bifurcation Theory which is limited to the non-linear phenomena observed by the author when he analyzed high performance aircraft behavior. In particular, complex bifurcations and chaotic motions are not treated. Numerical procedures developed to use results from Bifurcation Theory are presented. Then, some remarks are stated to establish a connection between asymptotic and quasi-stationary behavior. Finally, a methodology dedicated to the analysis of non-linear systems is proposed. Author (revised)

N94-18239# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
STABILITY ANALYSIS THROUGH BIFURCATION THEORY, 2
P. GUICHETEAU *In* AGARD, Non Linear Dynamics and Chaos 11 p (SEE N94-18236 04-77) Jun. 1993
(AGARD-LS-191) Copyright Avail: CASI HC A03/MF A02

This communication follows a previous communication which was presented in the same Agard Lecture Series (LS 191). In the previous communication, some theoretical foundations of Bifurcation Theory were recalled and a methodology aiming at a systematic prediction of the behavior of non-linear differential equations was presented. This communication mentions some problems which are connected with the introduction of control laws in order to stabilize an unstable dynamic system and presents a brief state of the art related to the determination of the attracting region of a stable equilibrium point. Author (revised)

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ADMINISTRATION AND MANAGEMENT

Includes management planning and research.

N94-30934# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
MARKETING TOOLS FOR INCREASING PROACTIVITY IN TECHNICAL INFORMATION CENTERS [LES OUTILS DE MARKETING DANS LA STIMULATION DE LA PROACTIVITE AU SEIN DES INFOCENTRES]
CHRISTINE A. OLSON (Olson, Christine A. and Associates, Arnold, MD.) Feb. 1994 47 p
(AGARD-AR-326; ISBN-92-835-0737-1) Copyright Avail: CASI HC A03/MF A01

This publication is based on a presentation to the Technical Information Panel of AGARD given in April 1993 in Rome, Italy. It discusses the 'marketing' of library and information services, necessary even for services which do not charge their users, from a number of different aspects such as the need for a marketing information system, market research, positioning, products, pricing, placement, promotion, public relations, planning and auditing. Author

N94-37447# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
A GUIDE TO TENDERS AND CONTRACTS ALERTING SERVICES [GUIDE DES SERVICES D'ANNONCES D'APPELS D'OFFRES ET DES MARCHES]
Mar. 1993 27 p
(AGARD-R-799; ISBN-92-835-0704-5) Copyright Avail: CASI HC A03/MF A01

This documents lists, for each of the NATO nations, the main services available for alerting potential bidders and others to government and defense tenders and contracts. This information was compiled by members of the Technical Information Panel of AGARD and the publication was sponsored by the panel. Author

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DOCUMENTATION AND INFORMATION SCIENCE

Includes information management; information storage and retrieval technology; technical writing; graphic arts; and micrography.

N92-32182# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
BRINGING DOWN THE BARRIERS TO INFORMATION TRANSFER [L'ABAISSEMENT DES BARRIERES S'OPPOSANT AU TRANSFERT DE L'INFORMATION]
Feb. 1992 143 p In ENGLISH and FRENCH Meeting held in Madrid, Spain, 8-9 Oct. 1991
(AGARD-CP-505; ISBN-92-835-0655-3) Copyright Avail: CASI HC A07/MF A02

The last few years have seen rapid advances in a number of new technologies aimed at improving the storage and retrieval of information. Information scientists may be aware of their potential but may have reservations concerning the absence of suitable standards or the short life associated with some developments. This conference brought together a group of experts to explain the practicalities of applying these new, powerful technologies, their successes and failures. Topics addressed included Artificial Intelligence, CD-ROM, Hypertext, and Local Area Networks. These topics were addressed within the framework of finding practical solutions to the problems of achieving efficient and effective information transfer. For individual titles, see N92-32183 through N92-32192.

N92-32184# Institut National des Sciences et Techniques Nucleaires, Saclay (France).
INTELLIGENT GATEWAYS [GATEWAYS 'INTELLIGENTS']
CHRISTIAN FLUHR and CLAUDINE MACHARD *In* AGARD, Bringing Down the Barriers to Information Transfer 8 p (SEE N92-32182 22-82) Feb. 1992 In FRENCH
(AGARD-CP-505) Copyright Avail: CASI HC A02/MF A02

Documentary databases that are accessible on-line are, at the present time, underused. This is due to several causes such as the difficulty in efficiently manipulating query languages, the heterogeneity of such languages, the diversity of middle-men with whom one must sign a contract to access the information, the clumsiness of the connection procedures, the costs, and the difficulty associated with choosing the best database. The problem of cost should be resolved as databases are used more effectively. The resolution of the difficulties cited above can be realized along different points of the information chain. It is possible to imagine the placement of considerable intelligence in the workstation of the searcher, but this would require large amounts of computing power. As an alternative, this could be done on a powerful autonomous system: the gateway. It is probably at this level that the majority of the problems could be the most easily resolved. It is for this reason that, even though a large part of what we will develop here can be placed in the workstation, we prefer to concentrate on the possible functionalities of gateways. The goal is not to list the functionalities proposed by existing gateways, but

to list the group that current technology allows in the short term. Author

N92-32185# Orleans Univ. (France).

USE OF EXPERT SYSTEMS AS USER INTERFACES IN INFORMATION RETRIEVAL [UTILISATION DES SYSTEMES EXPERTS DANS DES INTERFACES POUR LA RECHERCHE DOCUMENTAIRE]

J.-C. BASSANO, D. ARCHAMBAULT, G. DESROCQUES, and A. MAKAOUCHE *In* AGARD, Bringing Down the Barriers to Information Transfer 14 p (SEE N92-32182 22-82) Feb. 1992 In FRENCH

(AGARD-CP-505) Copyright Avail: CASI HC A03/MF A02

The interfaces in question present a text or a group of texts in response to the users' query. These interfaces provide the user with a wide variety of utilities. Efficient technologies for the progressive pairing of the 'sense' between the question and the document are discussed. In order to make the tools cooperate, it is suggested that we have passed from using monolithic interfaces to hybrid or 'multi-expert' architectures. The current evolution of research is in the area of 'connectionist' executions. Author

N92-32186# Technisch Documentatie en Informatie Centrum voor de Krijgsmacht, The Hague (Netherlands).

SEARCH STRATEGIES IN NATURAL LANGUAGE

B. H. A. ZIJLSTRA *In* AGARD, Bringing Down the Barriers to Information Transfer 39 p (SEE N92-32182 22-82) Feb. 1992

(AGARD-CP-505) Copyright Avail: CASI HC A03/MF A02

After a discussion of online searching problems, some methods for making online searching easy for end-users are described: Intelligent gateways, ZOOM, HYPERLINE, CD-ROM, and MENUS. Attention is given to parsing and natural language interfaces to databases, and then natural language projects such as CITE, OKAPI, PLEXUS/TOME/MITI, DIANEGUIDE/NL, DGIS/STINET, SPIRIT/EMIR, and Alpha DIDO are described. In the fourth chapter attention is given to Natural Language and Thesauri, such as the bilingual NATO Thesaurus. A bibliography was added. In an annex an example shows that End-users can start online searching with Natural Language terms, using ZOOM and HYPERLINE commands. Author

N92-32187# Glasgow Univ. (Scotland). Dept. of Computing Science.

NON BOOLEAN SEARCH METHODS IN INFORMATION RETRIEVAL

C. J. VANRIJSBERGEN *In* AGARD, Bringing Down the Barriers to Information Transfer 12 p (SEE N92-32182 22-82) Feb. 1992

(AGARD-CP-505) Copyright Avail: CASI HC A03/MF A02

Information retrieval is a wide, often loosely-defined term, but in these pages I shall be concerned only with automatic information retrieval systems; automatic as opposed to manual and information as opposed to data or fact. Unfortunately the word information can be very misleading. In the context of information retrieval (IR), information, in the technical meaning given in Shannon's theory of communication, is not readily measured. Nevertheless it has become apparent that there is a notion of information fundamental to the information retrieval process that underlies our intuitions about what it is we attempt to retrieve. In many cases one can adequately describe this kind of retrieval by simply substituting 'document' for 'information' where a document may be text, image, etc. This implies that the process is concerned with the identification of certain kinds of objects, viz. documents. It does not explain what is the basis of this identification process, and it is here that the notion of information plays a role. In the case of Boolean retrieval, an attempt is made to measure the extent to which the information is contained in a particular document by establishing whether a document satisfies the request. In the non-Boolean case, this process of satisfaction has a measure of uncertainty attached to it. This paper will explore methods for non-Boolean retrieval. Author

N92-32188*# National Aeronautics and Space Administration, Washington, DC.

HYPERTEXT AND HYPERMEDIA SYSTEMS IN INFORMATION RETRIEVAL

K. M. KAYE and A. D. KUHN *In* AGARD, Bringing Down the Barriers to Informations Transfer 5 p (SEE N92-32182 22-82) Feb. 1992

(AGARD-CP-505) Copyright Avail: CASI HC A01/MF A02

This paper opens with a brief history of hypertext and hypermedia in the context of information management during the 'information age.' Relevant terms are defined and the approach of the paper is explained. Linear and hypermedia information access methods are contrasted. A discussion of hyperprogramming in the handling of complex scientific and technical information follows. A selection of innovative hypermedia systems is discussed. An analysis of the Clinical Practice Library of Medicine NASA STI Program hypermedia application is presented. The paper concludes with a discussion of the NASA STI Program's future hypermedia project plans. Author

N92-32189# Fachhochschule, Darmstadt (Germany). Dept. of Computer Science.

AUTOMATED INPUT INTO DATABASES: OCR AND DESCRIPTIVE CATALOGUING

GERHARD E. KNORZ *In* AGARD, Bringing Down the Barriers to Information Transfer 10 p (SEE N92-32182 22-82) Feb. 1992 Sponsored by BMFT

(AGARD-CP-505) Copyright Avail: CASI HC A02/MF A02

The technology of automated input from written text into databases is discussed. The current emphasis in office automation and desktop publishing helped optical character recognition to become a useful and affordable method. Different approaches (pixel-oriented, feature-based, using dictionaries, using special algorithms for special problems, character transition probabilities, or grammars) form the basis for meeting different classes of requirements such as demanded by small fonts, large varieties of fonts, special characters, different layout structures with mixed text and graphics, difficult printed matters with ligatures and kerning, and poor printing quality. On the way to an automated (or semi-automated) input process from printed matters into databases (OCR) is nothing but a necessary step within the line of scanning, character recognition, descriptive cataloging, and (optional) content analysis. Cataloging here is to be understood in a broader sense convering the identification and classification of the relevant pieces of input and the normalization process according to database-specific rules. The role of efficient input into bibliographic databases is discussed, as well as problems and techniques of optical character recognition. AUTOCAT, a software prototype for automated cataloging is introduced: its foundation, approach, and user interface. Author

N92-32190# National Aerospace Lab., Emmeloord (Netherlands).

DATA COMPRESSION TECHNIQUES

R. A. HOGENDOORN *In* AGARD, Bringing Down the Barriers to Information Transfer 3 p (SEE N92-32182 22-82) Feb. 1992

(AGARD-CP-505) Copyright Avail: CASI HC A01/MF A02

Data compression can be used to reduce the volume of documents. This results in considerable savings on storage capacity and in transmission time. In general, there are two classes of compression techniques: reversible compression or statistical compression, with which documents can exactly be reproduced, and non-reversible or noisy compression, with which documents can be reproduced up to a given fidelity. Non-reversible compression most often gives a higher compression factor, but, obviously, at a price. Reversible algorithms are suitable for text compression and black-and-white images. Non-reversible algorithms are suitable for images. This paper describes the advantages and caveats of data compression. What is to be expected if data compression is used and, more important, what is not to be expected. Author

N92-32191# Canada Inst. for Scientific and Technical Information, Ottawa, Ontario (Canada). Scientific Numeric Database Service.
COMPUTERIZED PROPERTY DATA FOR ENGINEERING MATERIALS: AN OVERVIEW
GORDON H. WOOD *In* AGARD, Bringing Down the Barriers to Information Transfer 6 p (SEE N92-32182 22-82) Feb. 1992
(AGARD-CP-505) Copyright Avail: CASI HC A02/MF A02
The special problems of materials property databases, as opposed to scientific numeric databases, are described. A review of progress towards materials property databases since the seminal workshop of 1982 in Fairfield Glade, Tennessee is given based on the recent Third International Symposium on the Computerization and Use of Materials Property Data. Topics include standards and data representation, standards and database development, expert systems and materials databases, data issues for engineering materials, industrial applications, and working and prototype systems. Author

N92-32192# Defense Technical Information Center, Alexandria, VA. Office of Information Systems and Technology.
FACILITATING THE TRANSFER OF SCIENTIFIC AND TECHNICAL INFORMATION WITH SCIENTIFIC AND TECHNICAL NUMERIC DATABASES
H. HALLER *In* AGARD, Bringing Down the Barriers to Information Transfer 13 p (SEE N92-32182 22-82) Feb. 1992
(AGARD-CP-505) Copyright Avail: CASI HC A03/MF A02
The Defense Technical Information Center (DTIC) provides services primarily to librarians and technical information specialists. In an effort to better serve engineers and scientists, the end users, DTIC conducted a technology assessment of users and developers of scientific and technical numeric databases. DTIC's Department of Defense Gateway Information System (DGIS) provides the access mechanism to databases and the Multi-Type Information, and Data Analysis System (MIDAS) will provide the capabilities to process bibliographic information and numeric data. Author

N93-10593# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
SEMINAR ON BASIC DOCUMENTATION PRACTICES [LES PRATIQUES DE BASE EN MATIERE DE DOCUMENTATION]
Aug. 1992 192 p Seminar held in Ankara, Turkey, 3-4 Sep. 1992, in Athens, Greece, 7-8 Sep. 1992, and in Lisbon, Portugal, 10-11 Sep. 1992
(AGARD-R-788; ISBN-92-835-0681-2; AD-A255673; AD-A255822) Copyright Avail: CASI HC A09/MF A02
Application of new technology to the management of scientific and technical information relies upon a thorough grounding in basic concepts. The acquisition, storage, retrieval, and dissemination of material is becoming ever more complex and is a process which requires an understanding of how knowledge is perceived by the end user, the mechanics of data transfer, and the principles of responsible information exchange. In addition, the proliferation of information and the variety of media currently available make clear objectives and practical solutions essential. The AGARD Technical Information Panel (TIP) has produced a number of publications aimed at establishing and raising the standard of information management. This seminar brings together expert speakers to update the information in these publications and to contribute towards further improvement in basic documentation practices. For individual titles, see N93-10594 through N93-10603.

N93-10594# Scientific and Technical Research Council of Turkey, Ankara (Turkey). Documentation Center.
NATIONAL SCENE IN INFORMATION AND DOCUMENTATION ACTIVITIES AND RECENT DEVELOPMENTS IN THE DOCUMENTATION CENTER OF TUBITAK (TURDOK)
IMRE YILDIZ *In* AGARD, Seminar on Basic Documentation Practices 3 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A01/MF A02
The first section is based on the evaluation of the survey, conducted by the Documentation Center (TURDOK) of Scientific and Technical Research Council of Turkey (TUBITAK) on the existing national information and documentation activities in Turkey. The second section comprises the recent developments of TURDOK in providing information for universities, governmental institutions, and industry. Author

N93-10595# Hellenic Aerospace Industry, Schimatari (Greece). Technical and Scientific Library.
DOCUMENTATION PRACTICES: THE NATIONAL SCENE (GREECE)
D. PATRINOS *In* AGARD, Seminar on Basic Documentation Practices 10 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A02/MF A02
The information 'explosion' combined with the capabilities offered by the new technologies poses a new challenge to all those involved in documentation work: producers, librarians, documentation and information specialists, and users. An overview of current documentation practices in Greece is presented. It also addresses subjects associated with documentation work, such as standards, telecommunications networks, education and training, and library automation issues. It outlines the progress made in some areas during the recent years and attempts to identify the major problems related to the delayed implementation of modern means and practices in the Greek documentation environment. Author

N93-10596# Laboratorio Nacional de Engenharia e Tecnologia Industrial, Lisbon (Portugal). Centro de Informacao Tecnica para a Industria.
SCIENTIFIC AND TECHNICAL INFORMATION (STI) TOWARDS TECHNOLOGICAL AND INDUSTRIAL DEVELOPMENT: THE CASE OF PORTUGAL
ANA MARIA RAMALHO CORREIA *In* AGARD, Seminar on Basic Documentation Practices 16 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A03/MF A02
As a result of the rapid advancement of science and technology during the last decades, there is a tremendous increase in the accumulation of scientific, technical information (STI) and knowledge. The problem of collecting, cataloging, and accessing information to transfer to those who need it, when they need it, is a challenge faced by all information professionals. The application of information technologies to the management of STI represents an area where promising advancements are taking place, but where the user needs should be the 'push'. An overview is presented of the national scene in Portugal which covers some aspects related to different areas of scientific and technical information (SI) management and the application of new technologies to it. In particular, aspects related to the following are addressed: modernization of libraries; access to foreign databases (online and CD-ROM); advanced training in information management; development of information systems; development of advanced information products; participation in NATO programs in the field of STI; and research in information science in Portugal. Author

N93-10597*# National Aeronautics and Space Administration, Washington, DC.
ESTABLISHING A SCIENTIFIC AND TECHNICAL INFORMATION PROGRAM: PLANNING AND RESOURCE MANAGEMENT
WALTER R. BLADOS *In* AGARD, Seminar on Basic Documentation Practices 21 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A03/MF A02
In the last 50 years, technological advances have accelerated at a rate unprecedented in history. We are experiencing a tremendous expansion of scientific and technological effort in many directions, and the result is a fantastic increase in the accumulation of scientific and technical information (STI) and knowledge. An integral part of the research and development (R&D) process is the STI associated with it. STI is both a raw material (input) and a product (output) of this process. The topics addressed include the following: the value of STI, management of an STI program, program policy and guidance, organizational structure, data sources, training/orientation, and the current information environment. Author

N93-10598# GEC-Marconi Electronics Ltd., Chelmsford (England).
ACQUISITION 1: STOCK ACQUISITION PROCESSES IN DEFENCE AND AEROSPACE DOCUMENTATION CENTRES
CHRIS BIGGER *In* AGARD, Seminar on Basic Documentation Practices 9 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A02/MF A02

The acquisition of stock for any library is of course an essential activity, without stock there is no library and no service can be provided. It is sometimes difficult to find or create general rules because every library is different with different budgets, users, user needs, and organizational aims. Some general guidelines will be of some help but most decisions rest with the library after weighing all the evidence. Unless you are running a national library or a very large system it will not be possible to buy or acquire all that is published. Even if it could be acquired there may not be the space to store all stock. You are then forced to be selective due to the limits imposed by your organization. When stock has been selected it must be purchased at reasonable prices and at suitable speed. The acquisition of library stock is covered, and selection and acquisition processes are included, starting with the need for selection policies and moving on to establishing user needs, stock types, evaluation methods, purchase methods, and stock suppliers. Author

N93-10599# North Atlantic Treaty Organization, Brussels (Belgium). System Support Group.
ACQUISITION 2: PROCUREMENT, ACQUISITION, AND MAINTENANCE OF CONFIGURATION MANAGEMENT DOCUMENTATION IN SUPPORT OF A CIS SYSTEM
R. POOL *In* AGARD, Seminar on Basic Documentation Practices 12 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A03/MF A02

The procedures used by the NATO Communications and Information Systems Agency (NACISA), when acting as host nation for the implementation of a communications and information systems (CIS) project, are outlined. The procurement, acquisition, and maintenance of configuration management documentation required in support of a CIS are addressed. For the purposes of this exercise, configuration management documentation is defined as specifications, handbooks, drawings, and records that pertain to the design, performance, installation, operation, and maintenance of a CIS. Emphasis is on the activities involved in the acquisition of technical handbooks and drawings required for operation and maintenance, and the various end-users requiring this data are biefly outlined. In addition, the procedures currently used to maintain this documentation during the in-service phase of a CIS are described, and the present storage media utilized and future automation plans are addressed. Author

N93-10600# Federal Armed Forces Documentation and Information Centre, Bonn (Germany).
DOCUMENT PROCESSING
H. BRAUN *In* AGARD, Seminar on Basic Documentation Practices 25 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A03/MF A02

Information systems operating a referral-type database, need to produce references for their documents in order to successfully retrieve the information. The same references serve as an initial user information, thereby enabling the users to decide upon the information value of the document contents for their own specific requirements. The various steps in producing such references, the process we call document processing, are addressed: descriptive cataloging deals with the various bibliographic data of documents. Content analysis, subdivided into classifying, indexing, and abstracting, is discussed in some detail. The thesaurus as the main instrument of an indexer, its function, and its structure are described. Finally, the data of the reference are entered into the data base for information retrieval, while the document is stored in the document collection. Author

N93-10601*# National Aeronautics and Space Administration, Washington, DC.
TECHNOLOGY FOR LIBRARIES AND INFORMATION CENTERS: A SEMINAR IN GREECE, PORTUGAL, AND TURKEY
GLADYS A. COTTER *In* AGARD, Seminar on Basic Documentation Practices 36 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A03/MF A02

Information technologies are evolving at a rapid pace in today's world. But the electronic technologies needed to transform today's libraries and information centers into electronic 'libraries without walls', where an end-user has instantaneous access to all the information needed from a desktop workstation, have not yet arrived. Even so, there are many technologies available today that can be applied in the library/information center environment to yield increased productivity. However, not all technologies are right for or successful in every environment. Mission, budget, infrastructure, client profiles, and staff skills are a few of the 'environmental' issues that must be considered when selecting and introducing new technologies into a particular information center. Key technologies used in libraries today are reviewed; it can be used as background for targeting technologies that could be successfully implemented in your own environment to further service goals. Before focusing on a selection of technologies, you must first focus on the strategic goal of your organization. The same technology is not right for every library/information center. An overview of technologies that are readily available and can be applied today is presented. Author

N93-10602# GEC-Marconi Electronics Ltd., Chelmsford (England).
SERVICES: USER SERVICES IN DEFENCE AND AEROSPACE DOCUMENTATION CENTRES
CHRIS BIGGER *In* AGARD, Seminar on Basic Documentation Practices 8 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A02/MF A02

When the Library stock and layout have been considered, the question of exploiting the collection arises. If money has been invested in stock, staff, and equipment then maximum use must be obtained from them, otherwise the library is failing the parent organization or funder. Full exploitation will produce useful returns on the money invested and further support for library services and future funding. Use of a library means matching users to information in the collection and various library services are available to achieve this. These services are described, highlighting the options, benefits, and problems. It is hoped that the discussion presents a starting point for further investigation of each area. Loans, interlibrary loans, and circulation systems are discussed first followed by information services such as bulletins, inquiry services, online, and current awareness. Author

N93-10603# Federal Armed Forces Documentation and Information Centre, Bonn (Germany).
SECURITY CONSIDERATIONS WITHIN MILITARY INFORMATION SYSTEMS
H. BRAUN *In* AGARD, Seminar on Basic Documentation Practices 17 p (SEE N93-10593 01-82) Aug. 1992
(AGARD-R-788) Copyright Avail: CASI HC A03/MF A02

Military information systems, as well as systems operating in a governmental environment, will administer classified information as well as documents, which are not to be released to the public. Such information needs reliable protection against unintentional disclosure and unauthorized access. Advice on the principles of a security risk analysis is presented, and methods for adequate handling of sensitive information are outlined, considering objectives, requirements, and functions of network security. Author

N93-10610# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
AGARD INDEX OF PUBLICATIONS, 1989-1991 [INDEX DES PUBLICATIONS, 1989-1991]
Jul. 1992 520 p
(AGARD-INDEX-89-91; ISBN-92-835-0682-0; AD-A255629)
Copyright Avail: CASI HC A22/MF A04

This volume provides abstracts and indexes for AGARD unclassified publications published during the period 1989-1991. Full bibliographical citations and abstracts for all the documents in this publication are given in the abstract section, which is organized in the major subject divisions and specific categories used by NASA in abstract journals and bibliographies. The major subject divisions are listed, together with a note for each that defines its scope and provides any cross-references. Category breaks in the abstract section are identified by category number and title, and a scope note. Within each category, the abstracts are arranged by series and year. Six indexes -- subject (based on NASA Thesaurus nomenclature), personal author, corporate source, panel, report/accession number, and accession number -- are included. Sample entries are shown on the first page of each index. Author

N93-11710# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
DIRECTORY OF FACTUAL AND NUMERIC DATABASES OF RELEVANCE TO AEROSPACE AND DEFENCE R AND D [REPERTOIRE DE BASES DE DONNEES FACTUELLES OU NUMERIQUES D'INTERET POUR LA R ET D]
Jul. 1992 110 p
(AGARD-R-777; ISBN-92-835-0680-4; AD-A255622) Copyright Avail: CASI HC A06/MF A02

Information is presented on nearly 100 unclassified factual or numeric databases of potential interest to aerospace and defense research and development. Information given in this directory includes the name of the organization and a point of contact, the title of the databank and the type of data included, a description of its coverage, information on the form of output available, and details of software used. The directory is listed in order by NASA subject category. This publication was sponsored by the Technical Information Panel of AGARD. DTIC

N93-19796# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
A RESEARCH AGENDA FOR SCIENTIFIC AND TECHNICAL INFORMATION [UN PROGRAMME DE RECHERCHE POUR L'INFORMATION SCIENTIFIQUE ET TECHNIQUE]
Nov. 1992 61 p Workshop held in Lisbon, Portugal, 7-9 Apr. 1992
(AGARD-AR-316; ISBN-92-835-0691-X) Copyright Avail: CASI HC A04/MF A01

The results of a workshop are presented and includes three position papers on user needs, information access, and the organization and transfer of information, prepared by the authors as a result of the discussions at the workshop. The outcome of the workshop, in the form of a 53-item research agenda, is given under the headings: information management; provision of information; and access to information. Each is examined from the aspects of human resources, quality assurance, cost, and technology, where appropriate. The report also includes a list of 15 additional areas meriting further investigation, which were identified by participants, during the final session of the workshop. For individual titles, see N93-19797 through N93-19800.

N93-19797*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ESTABLISHING A RESEARCH AGENDA FOR SCIENTIFIC AND TECHNICAL INFORMATION (STI): FOCUS ON THE USER
THOMAS E. PINELLI *In* AGARD, A Research Agenda for Scientific and Technical Information 11 p (SEE N93-19796 06-82) Nov. 1992 Previously announced in IAA as A92-48392
(AGARD-AR-316) Copyright Avail: CASI HC A03/MF A01

This report addresses the relationship between library science and information science theory and practice, between the development of conceptual understanding, and the practical competence of information professionals. Consideration is given to the concept of research, linking theory with practice, and the reality of theory based practice. Attention is given to the need for research and research priorities, focus on the user and information-seeking behavior, and a user-oriented research agenda for STI. Author

N93-19798# Simmons Coll., Boston, MA.
INFORMATION ACCESS: A RESEARCH AGENDA
PETER HERNON *In* AGARD, A Research Agenda for Scientific and Technical Information 18 p (SEE N93-19796 06-82) Nov. 1992
(AGARD-AR-316) Copyright Avail: CASI HC A03/MF A01

This paper provides a general overview of information access. The issues identified and discussed ultimately have implications for both developed and developing countries. It is important that developing countries recognize and address these issues in national plans and in practice, for the issues relate to information resources management and use, and to scientific, economic, technological, and societal advancement. The proposed research agenda represents an initial effort to offer direction in an information and electronic age. The agenda provides nations, international bodies, agencies, and organizations with a flexible framework for producing change and for linking that change to decision making and policy review, formulation, and implementation. Author

N93-19799# University Coll., London (England). Dept. of Computer Science.
THE ORGANIZATION AND TRANSFER OF INFORMATION
BILL TUCK *In* AGARD, A Research Agenda for Scientific and Technical Information 11 p (SEE N93-19796 06-82) Nov. 1992
(AGARD-AR-316) Copyright Avail: CASI HC A03/MF A01

The objective of this workshop is to develop a research agenda for management and policy issues relating to scientific and technical information. The intention is not only to inform but also to elicit recommendations for further research and study. In particular, it will be important to determine just what it is we do not fully understand, and also to assess the effectiveness of our programs. These two concepts - 'understanding' and 'effectiveness' - form the underlying themes of the following paper. They are not unrelated: it is clearly a possibility that our programs may be ineffective because we do not fully understand the issues on which they are dependent. Conversely, improving their effectiveness will almost certainly require more detailed knowledge of the underlying dynamics. The class of problems toward which this paper is addressed is concerned with the organization and transfer of information. What barriers exist to the effective retrieval and transfer of scientific and technical information? And how does one ensure the quality and integrity of that information? These are complex issues only partly addressed in the present paper, which is intended to provoke discussion rather than provide detailed solutions. Author

N93-19800*# National Aeronautics and Space Administration, Washington, DC.
THE AGARD TIP RESEARCH AGENDA FOR SCIENTIFIC AND TECHNICAL INFORMATION (STI)
WALTER R. BLADOS *In* AGARD, A Research Agenda for Scientific and Technical Information 4 p (SEE N93-19796 06-82) Nov. 1992
(AGARD-AR-316) Copyright Avail: CASI HC A01/MF A01

The Research Agenda contains three themes: information management, provision of information, and access to information. Provision of information is further divided into two subordinate themes, dissemination and bibliographic control; access to information is also further divided into two subordinate themes, barriers and equity and networking. Each theme or sub-theme was examined from four possible aspects, namely, human resources, quality assurance, cost, and technology. It was concluded that, in fact, a theme or sub-theme need not contain all four aspects. Author

N93-31215# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.

THE IMPACT OF CHANGING INTERNATIONAL RELATIONS ON THE SCIENTIFIC AND TECHNICAL COMMUNITY [INCIDENCE SUR LA COMMUNAUTE SCIENTIFIQUE ET TECHNIQUE DES TRANSFORMATIONS EN COURS DANS LES RELATIONS INTERNATIONALES]

Apr. 1993 99 p Specialists' Meeting held in Copenhagen, Denmark, 14-15 Oct. 1992

(AGARD-CP-523; ISBN-92-835-0708-8; AD-A265919) Copyright Avail: CASI HC A05/MF A02

The papers from the Technical Information Panel's Specialists' Meeting, held in Copenhagen, Denmark on 14-15 Oct. 1992, are presented. The following topics are covered: the interaction between technology and culture, an overview of recent political changes, the effects on the exchange of scientific and technical information of these changes and consequent economic ones, the problems of managing change, forecasting and planning for change, and some of the new technologies that will help to overcome the problems raised by these changes. For individual titles, see N93-31216 through N93-31223.

N93-31216# Commission of the European Communities, Brussels (Belgium).

THE EFFECT OF CHANGES IN MARKETS AND TRADE BARRIERS ON THE EXCHANGE OF SCIENTIFIC AND TECHNICAL INFORMATION

BRIDGET CZARNOTA *In* AGARD, The Impact of Changing International Relations on the Scientific and Technical Community 3 p (SEE N93-31215 12-82) Apr. 1993

(AGARD-CP-523) Copyright Avail: CASI HC A01/MF A02

The purpose of this paper is to examine the consequences of changes in markets and trade barriers in the exchange of scientific and technical information. The European Community is a particularly appropriate starting point to examine such a question since, as presently constituted, it represents a market of over 30 million people brought together in a single market by virtue of the Treaty of Rome. Undoubtedly, at the time of the signing of that Treaty by the original members of the Community, the same question was asked, namely, how will economic union affect the distribution and circulation of information. Undoubtedly, each Member State that has subsequently joined the market has raised the same issue. And it is certainly a question which arises in a particularly vivid form by the non-static nature of the Community itself. Over and above the Internal Market as we currently know it, we have other dimensions which we must take into account. One of these dimensions is of course that of Maastricht--the question of how far towards closer monetary and political union the Member States are ready to go. The responsibilities will be extended in policy areas such as the environment, consumer protection, health, and education. One of the crucial questions is whether all these far reaching advances in policy areas will finally lead to a European identity. Many commentators however, now focus on Maastricht as a turning point in the Community's history without understanding the realities of the existing market. Author (revised)

N93-31217*# NASA Center for AeroSpace Information, Linthicum Heights, MD.

NEWLY AVAILABLE TECHNOLOGIES PRESENT EXPANDING OPPORTUNITIES FOR SCIENTIFIC AND TECHNICAL INFORMATION EXCHANGE

JEAN M. TOLZMAN *In* AGARD, The Impact of Changing International Relations on the Scientific and Technical Community 12 p (SEE N93-31215 12-82) Apr. 1993 Previously announced as N93-22470 Sponsored by NASA, Washington

(AGARD-CP-523) Copyright Avail: CASI HC A03/MF A02

The potential for expanded communication among researchers, scholars, and students is supported by growth in the capabilities for electronic communication as well as expanding access to various forms of electronic interchange and computing capabilities. Increased possibilities for information exchange, collegial dialogue, collaboration, and access to remote resources exist as high-speed networks, increasingly powerful workstations, and large, multi-user computational facilities are more frequently linked and more commonly available. Numerous writers speak of the telecommunications revolution and its impact on the development and dissemination of knowledge and learning. One author offers the phrase 'Scholarly skywriting' to represent a new form of scientific communication that he envisions using electronic networks. In the United States (U.S.), researchers associated with the National Science Foundation (NSF) are exploring 'nationwide collaboratories' and 'digital collaboration.' Research supported by the U.S. National Aeronautics and Space Administration (NASA) points to a future where workstations with built-in audio, video monitors, and screen sharing protocols are used to support collaborations with colleagues located throughout the world. Instruments and sensors located worldwide will produce data streams that will be brought together, analyzed, and distributed as new findings. Researchers will have access to machines that can supply domain-specific information in addition to locator and directory assistance. New forms of electronic journals will emerge and provide opportunities for researchers and scientists to exchange information electronically and interactively in a range of structures and formats. Ultimately, the wide-scale use of these technologies in the dissemination of research results and the stimulation of collegial dialogue will change the way we represent and express our knowledge of the world. A new paradigm will evolve--perhaps a truly worldwide 'invisible college.'

Author (revised)

N93-31218# Ministry of Education and Research, Copenhagen (Denmark).

INTEGRATED ACCESS TO DISTRIBUTED DATABASES THROUGH INTELLIGENT INTERFACES

INGE BERGHANSEN *In* AGARD, The Impact of Changing International Relations on the Scientific and Technical Community 7 p (SEE N93-31215 12-82) Apr. 1993

(AGARD-CP-523) Copyright Avail: CASI HC A02/MF A02

The IANI interface is one of many attempts to produce efficient access to databases on different hosts. IANI stands for Intelligent Access to Nordic Information and was started as a project by the Nordic Council for Scientific Information in 1986. The aim of the project was to produce an interface which would allow Nordic users to access Nordic databases with one login procedure and one command language. The development of the prototype was a true cooperative exercise involving the Danish contractor CRI and the hosts of union catalogues in Denmark, Finland, and Sweden. After implementation of the prototype software, a Norwegian union catalogue host was added. The prototype was developed for an IBM-compatible PC. Later, the software was ported to a UNIX machine where IANI may serve as a gateway in specific applications. It has been used in an information training scheme by the Ministry of Education for Danish school children. The IANI concept has turned out to be a useful tool for integration of groups of databases. In 1991 it was used for integrated access to the catalogues of libraries of the major European Institutions in the EUROLIB-project. The attempts to integrate the database world through IANI have demonstrated that it is feasible to produce integrated database access in a few weeks. Experience has, however, also shown that database and network access procedures are changed so frequently, that the maintenance costs for interface products are high. The next step on the way towards integration of databases is expected to be implementation of the new ISO Search and Retrieve Standard which now is being used in pilot projects sponsored by NORDINFO and the Commission of EC. The paper concludes with a recommendation to use the many interface prototypes which have been produced in international R&D programs, but still need further development in order to become stable products which can be sold to the information world. Author (revised)

N93-31219# Siemens A.G., Munich (Germany).

AUTOMATING MULTILINGUAL COMMUNICATION

THOMAS SCHNEIDER *In* AGARD, The Impact of Changing International Relations on the Scientific and Technical Community 4 p (SEE N93-31215 12-82) Apr. 1993

(AGARD-CP-523) Copyright Avail: CASI HC A01/MF A02

The integration of Europe and the increasing economic interdependence across continents require an increasing amount of communication across linguistic boundaries. The need for rapid information transfer cannot be met by conventional methods of translation. Thus, the introduction of machine translation seems inevitable. If, in the past, MT systems had not been entirely successful, advances in hardware as well as linguistic approaches have led to the development of viable systems. In the following,

the structure of one such operative system will be described in detail. Author (revised)

N93-31220# Technical Univ. of Norway, Trondheim. Dept. of Information Retrieval.

END USERS: NEW PRODUCTS AND SERVICES

AUD LAMVIK *In* AGARD, The Impact of Changing International Relations on the Scientific and Technical Community 3 p (SEE N93-31215 12-82) Apr. 1993

(AGARD-CP-523) Copyright Avail: CASI HC A01/MF A02

The database industry is young. Twenty to twenty-five years ago online databases were little more than a dream, and most of us didn't even dream about CD-ROM and multimedia databases. Much has happened in this business since the first databases took off. The Nordic countries entered the database scene early. In Sweden, the SDI service EPOS/VIRA was started as early as in 1967, and in 1972 the first on-line service, MIC/MEDLARS, was set up in Stockholm, hosting databases mainly within medical disciplines. Both services got users from all of the Nordic countries. In the same period, online searching at hosts such as DIALOG and ESA-IRS got a start, and several Nordic databases emerged--with various search languages on several hosts in each country. At the end of the 70's online searching was relatively well established in science and technology (including medicine). The users were primarily intermediaries in university and research libraries, i.e., scientists and engineers in the libraries. A survey within European countries in 1987 showed that the persons involved in searching were 'still mainly scientists and engineers.' End users are today important market groups for database producers and hosts. Much of the growth in database usage has been expected here. Numerous products and services have been introduced for easier and more efficient information retrieval and management to attract end users. Author (revised)

N93-31221# Orsted Inst., Copenhagen (Denmark). Inst. of Mathematics.

THE MODERN RESEARCH ENVIRONMENT

FLEMMING TOPSOE *In* AGARD, The Impact of Changing International Relations on the Scientific and Technical Community 5 p (SEE N93-31215 12-82) Apr. 1993

(AGARD-CP-523) Copyright Avail: CASI HC A01/MF A02

Information Technology and the scientific and technical communities are discussed. The following topics are addressed: the ideal user community, the ideal user platform, the ideal user support organization, the significance of structure, Networked Information Retrieval (NIR), Euromath and EmNet, and collaboration with Central and Eastern Europe. Author (revised)

N93-31222# Hudson Rivers Consultancy, Woodford Green (England).

THE MANAGEMENT OF CHANGE: IMPLICATIONS FOR THE INFORMATION PROFESSIONAL

BERYL MORRIS *In* AGARD, The Impact of Changing International Relations on the Scientific and Technical Community 3 p (SEE N93-31215 12-82) Apr. 1993

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All organizations are facing considerable pressures which have led to unprecedented change. In the paper I would like to address some of the drivers for change in the information world and look at the impact on the information professional. I thought I would conclude with some of the concepts which will be essential to our survival and, I hope, prosperity in the future. Author (revised)

N93-31223# Information International Associates, Inc., Oak Ridge, TN.

FORECASTING AND PLANNING FOR CHANGING PATTERNS OF SCIENTIFIC AND TECHNICAL COMMUNICATION (STC)

BONNIE C. CARROLL *In* AGARD, The Impact of Changing International Relations on the Scientific and Technical Community 23 p (SEE N93-31215 12-82) Apr. 1993

(AGARD-CP-523) Copyright Avail: CASI HC A03/MF A02

There are many changes taking place today in the methods and conduct of research and development. These changes have impact and are impacted by the methods of scientific and technical communication. The rapid advances in information technology (computing, telecommunications, and user interfaces) is a root cause of much of this change. The paper will begin by setting the stage with an overview of some issues, statistics, and conclusions about changing patterns in scientific and technical communications system. It will then review plans and strategies of nations and major organizations that were put forward to deal with the changing nature of the information infrastructure and system. Highlights from the following countries will be included: the United States, Germany, and Japan. For the United States, a more highly focused review will be made of areas of interest to AGARD. This will include directions for the NASA Scientific and Technical Information Program in the United States. Responses to the management of changing conditions will be highlighted throughout the paper. In conclusion, comparisons among strategies as well as the relationship between strategies and the fundamental changes in research and development communications will be made. Author (revised)

N94-15437# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.

ELECTRONIC MESSAGING FOR THE 1990'S Report No. 309 [LES MESSAGERIES ELECTRONIQUES DES ANNEES 90]

JEAN MOURAIN May 1993 44 p In ENGLISH and FRENCH

(AD-A267143; AGARD-AR-309; ISBN-92-835-2117-X; AD-A267564) Copyright Avail: CASI HC A03/MF A01

Electronic messaging systems, including their general principles, potential uses for transmitting information between people and between applications, problems of compatibility and possible solutions, messaging and data formats, and system architecture are discussed as well as the advantages and disadvantages of these systems in relation to competitors such as telefax, and the risks inherent in introducing them and ways of overcoming these risks. This publication is concluded with recommendations for AGARD (NATO's Advisory Group for Aerospace Research and Development). This publication was sponsored by the Technical Information Panel of AGARD. The volume contains the original French text and a translation into English. Author

N94-29342# Alenia Spazio S.p.A., Rome (Italy).

APPLICATION OF INFORMATION MANAGEMENT METHODOLOGIES FOR PROJECT QUALITY IMPROVEMENT IN A CHANGING ENVIRONMENT

FABRIZIO SANDRELLI *In* AGARD, Aerospace Software Engineering for Advanced Systems Architectures 6 p (SEE N94-29315 08-61) Nov. 1993

(AGARD-CP-545) Copyright Avail: CASI HC A02/MF A03

In the technologically advanced field of avionics, quality is required both by the market and the engineers. This means that quality is not only a goal to reach new customers, but is a different way of working which aims to reach a higher and more satisfactory working environment. The attention has been focused on the technical information produced during the development of the project and its diffusion through the technical and managerial environment. The goal is to improve the quality of the whole development process where the quality of the final products improves as a consequence. A methodology experienced in the last few years in ALENIA (Pomezia Plant) to plan, achieve, and manage a more flexible and advanced way of working, through the strong involvement of all who contribute to the realization of the product, is described. Attention was focused both on the organizational aspect of the project and the product configuration. These two aspects are self related and result in a correct management of the project. Author (revised)

N94-37333# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.

INTERNATIONAL HIGH SPEED NETWORKS FOR SCIENTIFIC AND TECHNICAL INFORMATION [LES RESEAUX INTERNATIONAUX RAPIDES D'ECHANGE D'INFORMATION SCIENTIFIQUE ET TECHNIQUE]

Feb. 1994 99 p In ENGLISH and FRENCH Meeting held in Ottawa, Ontario, 6-7 Oct. 1993

(AD-A278021; AGARD-CP-544; ISBN-92-835-0736-3) Copyright Avail: CASI HC A05/MF A02

Contains the papers presented at the Technical Information Panel's Specialists' Meeting held in Ottawa, Canada, 6-7 Oct. 1993. Subjects covered include description of Internet and other global information networks, the virtual library, the supply of documents,

electronic journals, bulletin boards, electronic mail and conferencing, information systems for unstructured files, standards, training, and a view of the future. For individual titles, see N94-37334 through N94-37346.

N94-37334# National Library of Canada, Ottawa (Ontario).
AN INTRODUCTION TO THE INTERNET AND ITS SERVICES
GARY CLEVELAND *In* AGARD, International High Speed Networks for Scientific and Technical Information 4 p (SEE N94-37333 12-82) Feb. 1994
(AGARD-CP-544) Copyright Avail: CASI HC A01/MF A02

The emergence of research networks, computer networks that serve academic and educational communities, offer libraries throughout the world the opportunity to enhance library resource sharing and information access. The best known example of this structure are the networks collectively known as the Internet. The Internet is actually a conglomeration of thousands of networks found in North America, Europe, and every other continent. It is a 'metanetwork' that: 1) physically interconnects TCP/IP-based networks, many of which have hundreds of component networks; and 2) provides gateways to other types of networks, such as BITNET, an electronic mail network that supports computer communications through 32 countries. This paper provides a nontechnical, high-level overview of the Internet and its services. Specific topics include a description of the Internet, how it began, and its current size; its overall structure; the types of international networks it interconnects; the network services that are available; and how these network services are used by libraries.
Author (revised)

N94-37335# European Space Agency. ESRIN, Frascati (Italy). Projects and Engineering Dept.
GLOBAL INFORMATION NETWORKS: HOW THEY WORK
ANGELO BODINI *In* AGARD, International High Speed Networks for Scientific and Technical Information 11 p (SEE N94-37333 12-82) Feb. 1994
(AGARD-CP-544) Copyright Avail: CASI HC A03/MF A02

'Network' is a word largely used today in many different contexts, and its meaning is highly dependent on the context. This paper focuses on telecommunications networks. A first distinction is introduced between networks structures, services provided by networks, and services provided by hosts connected to networks. Information services belong normally to the last category. Connectivity is highlighted as a basic network service, to support interactive communications, end-to-end file transfers, and data dissemination. Higher level network functions, such as electronic mail, conferences, bulletin boards, and directories make use of lower level connectivity functions but provided services of a different nature, referred to as value added services (VAS). Examples of this classification, which is mapped along the OSI reference model, are taken from Packet Switched Networks, Internet, Decnet, EARN/Bitnet and the protocols mostly used are outlined. A similar classification is to be made also for the gateways, i.e. devices and systems which interconnect different heterogeneous networks. The importance of gateways is invaluable, being the key to multiplying the connectivity of individual network implementations and fundamental steps towards the creation of a global virtual network for information services. Author (revised)

N94-37336# Industry and Science Canada, Ottawa (Ontario). Information Technologies.
THE CANADIAN NETWORK FOR THE ADVANCEMENT OF RESEARCH, INDUSTRY AND EDUCATION (CANARIE)
W. J. PADDEN *In* AGARD, International High Speed Networks for Scientific and Technical Information 2 p (SEE N94-37333 12-82) Feb. 1994
(AGARD-CP-544) Copyright Avail: CASI HC A01/MF A02

The extension of voice communications to include the simultaneous telecommunication of data, text, and imagery in combined multimedia formats provides researchers with a radically new means of engaging in collaborative research and development with one another. Being able to simultaneously share and manipulate the same images and data on a given topic appearing on their computer screens, at any distance from one another, while at the same time being able to converse on that topic, promises more innovative, more efficient, and less time-consuming ways of conducting research and development. Whereas the speed of computers has risen exponentially over the past two decades, the capacity of telephone lines to carry the data that computers are capable of generating has not kept pace, albeit for very justifiable reasons associated with the traditional environment of the telephone industry. Consequently, governments around the world are fostering the development of very high speed transmission facilities and international telecommunications protocols, as exemplified by the Open Systems Interconnection (OSI) models, in order to exploit the social and economic benefits of multimedia networking in business, research, and education. CANARIE is a proposed, national, high-speed backbone network which, when fully implemented in a multimedia format, will enable engineers and research scientists in any field, and in laboratories anywhere in Canada, to collaborate with one another and with their international colleagues on research and development projects of common interest, without the inhibitions presently imposed by the lack of proximity to one another. It may be anticipated that this 'shortening of economic distance' among them will lead to an increase in research and development activity and improvements in their productivity. It will also tend to accelerate the diffusion of technology from the laboratories into marketable products, and serve as a model for improving performance, hence competitiveness, in every sector of the economy.
Derived from text

N94-37337# Knowledge Exchange Technologies Ltd., Strassen (Luxembourg).
STANDARDS FOR DATA AND DOCUMENT INTERCHANGE
GEOFFREY A. STEPHENSON *In* AGARD, International High Speed Networks for Scientific and Technical Information 9 p (SEE N94-37333 12-82) Feb. 1994
(AGARD-CP-544) Copyright Avail: CASI HC A02/MF A02

In this paper I have tried to give an overview of the importance of standards for document interchange and an idea of where we are at present. There is a growing demand for documents in an electronic form to be interchanged between different platforms and software environments. Standards exist to enable most information to be interchanged in an application neutral way. The main barrier to such interchange is lack of awareness of the methods available and a lack of communication between users and vendors as to the priority of improving interchange. Users have to make their priorities clear to vendors if they are to be offered the facilities they require in the application packages they want to use. Author

N94-37338*# National Aeronautics and Space Administration, Washington, DC.
THE VIRTUAL LIBRARY: COMING OF AGE
JUDY F. HUNTER and GLADYS A. COTTER *In* AGARD, International High Speed Networks for Scientific and Technical Information 6 p (SEE N94-37333 12-82) Feb. 1994
(AGARD-CP-544) Copyright Avail: CASI HC A02/MF A02

With the high speed networking capabilities, multiple media options, and massive amounts of information that exist in electronic format today, the concept of a 'virtual' library or 'library without walls' is becoming viable. In virtual library environment, the information processed goes beyond the traditional definition of documents to include the results of scientific and technical research and development (reports, software, data) recorded in any format or media: electronic, audio, video, or scanned images. Network access to information must include tools to help locate information sources and navigate the networks to connect to the sources, as well as methods to extract the relevant information. Graphical User Interfaces (GUI's) that are intuitive and navigational tools such as Intelligent Gateway Processors (IGP) will provide users with seamless and transparent use of high speed networks to access, organize, and manage information. Traditional libraries will become points of electronic access to information on multiple medias. The emphasis will be towards unique collections of information at each library rather than entire collections at every library. It is no longer a question of whether there is enough information available; it is more a question of how to manage the vast volumes of information. The future equation will involve being able to organize knowledge, manage information, and provide access at the point of origin. Author

N94-37339# Tsentralni Aerogidrodinamicheskii Inst., Moscow (USSR).

PROBLEMS OF INTERNATIONAL EXCHANGE OF SCIENTIFIC AND TECHNICAL INFORMATION FOR A RUSSIAN AEROSPACE RESEARCH INSTITUTE

VICTOR M. TYURIN *In* AGARD, International High Speed Networks for Scientific and Technical Information 5 p (SEE N94-37333 12-82) Feb. 1994

(AGARD-CP-544) Copyright Avail: CASI HC A01/MF A02

The problems of international exchange of scientific and technical information for an aerospace research institute in Russia arise from this research area being classified; publications were strictly limited. This resulted in absence of specialized data bases; there is very little amount of information prepared properly for utilization in electronic networks. The other problem is underdevelopment of domestic networks for information exchange; there are not channels for connection with international networks. Changes in Russian policy and economics necessitate settling these problems for increasing efficiency of the organizations. There exists a plan to develop multibranch high-speed information-exchange networks, each having a coordination/control center connected with international networks. Author

N94-37340# Canada Inst. for Scientific and Technical Information, Ottawa, Ontario (Canada).

ELECTRONIC DOCUMENT DELIVERY: TOWARDS THE VIRTUAL LIBRARY

M. BRANDRETH and C. MACKEIGAN *In* AGARD, International High Speed Networks for Scientific and Technical Information 4 p (SEE N94-37333 12-82) Feb. 1994

(AGARD-CP-544) Copyright Avail: CASI HC A01/MF A02

Reduced funding, global competition and technological change are forcing libraries and information centers to turn to new methods of providing services. Publishers of scientific and technical information expect printed journals to remain their primary product for several more years, despite the advent of electronic journals. Library collections will continue to be largely paper-based, but clients will demand much faster document delivery services from them. Many libraries must also maximize the investment in their collections by expanding their clientele. Electronic scanning of documents coupled with transmission over high speed, high capacity networks offers a potential solution to these problems. For more than a year, CISTI has been using proprietary imaging workstations to supply documents to one of its Branches. Much more flexibility is needed to reach the disparate receiving equipment used by a varied Canadian and international clientele. The paper describes experience with the Ariel Workstation, able to transmit to a variety of receivers including identical scanning workstations, other workstations, facsimile machines, and microcomputers with facsimile boards. Ability to rationalize library collections is seen as an important consequence. Author

N94-37341# Institute for Scientific and Technical Information, Vandoeuvre-les-Nancy (France).

PROVIDING ELECTRONIC DOCUMENTS IN EUROPE: EXPERIENCE OF INIST [LA FOURNITURE DE DOCUMENTS ELECTRONIQUES EN EUROPE: L'EXPERIENCE DE L'INIST]

CHRISTIAN LUPOVICI *In* AGARD, International High Speed Networks for Scientific and Technical Information 5 p (SEE N94-37333 12-82) Feb. 1994 In FRENCH

(AGARD-CP-544) Copyright Avail: CASI HC A01/MF A02

The creation of the Institute for Scientific and Technical Information (INIST - Institut de l' Information Scientifique et Technique) in France in 1988, was the result of a decision from the Ministry on Research to develop a multidisciplinary department in charge of creating a data base in documentation center, for the diffusion of scientific and technical information, for French, European, and international researchers. The most modern technologies were adopted. For each step of acquisition of data, a specific technology was adapted and integrated in the general information system, from the time the documents were acquired to the creation of the data base and the production of primary documents: PASCAL for Science, Technology, and Medicine, FRANCIS for Social and Human Sciences. There are 5 steps in the INIST chain of production: management and classification of documents, using a GEAC 9000 system; analytical indexing of articles in periodicals and creation of abstracts (This work being done on computers and subcontracted to a private firm); numerical classification; storage of document on optical systems; and management of the system created to order and receive documents. The main technological challenges of the Hermes program are perfecting the thermal protection systems, developing fuel batteries, and designing the aerodynamics of the vehicle. This article presents what methods and means have been adopted to define the shapes which will satisfy the objectives of atmospheric travel. Author

N94-37342# Loughborough Univ. of Technology (England). HUSAT Research Inst.

ELECTRONIC JOURNALS

CLIFF MCKNIGHT *In* AGARD, International High Speed Networks for Scientific and Technical Information 6 p (SEE N94-37333 12-82) Feb. 1994

(AGARD-CP-544) Copyright Avail: CASI HC A02/MF A02

In 1981 a Royal Society study of the scientific information system in the UK described the electronic journal as 'perhaps the most radical innovation in prospect for the primary literature'. Twelve years and as many projects later, has the electronic journal gone any way towards realizing its potential? In order to answer this question, it is necessary to consider what the electronic journal has to offer. Or, to put it another way, what is wrong with the paper journal? The common criticisms of the paper journal are that they are often not on the shelf (mis-shelved, gone for binding, being used by someone else); they are hard to search through; they take up too much space; and there are too many of them to keep up with. In contrast, electronic journals are always there (assuming the network hasn't crashed); easy to search (but can flood you with hits unless you are careful in the way you conduct your search); and occupy much less space. In addition, various electronic 'filters' can be used to ensure that users receive notification of relevant journals - the 'selective dissemination of information' or SDI. These are the commonly attributed general advantages of electronic journals. However, they do not seem yet to have been sufficient to establish the electronic journal firmly in the scholarly communication chain. In order to see why this is the case, some of the electronic journal experiments are considered. Finally, suggestions are made regarding problems remaining to be tackled. Derived from text

N94-37343# Consejo Superior de Investigaciones Cientificas, Madrid (Spain). Centro Tecnico de Informatica.

BULLETIN BOARDS, ELECTRONIC MAIL, CONFERENCING, CURRENT USE BY SCIENTISTS AND ENGINEERS: EFFECTS ON LIBRARIES AND INFORMATION CENTRES: DO THEY HAVE A ROLE?

VICTOR CASTELO *In* AGARD, International High Speed Networks for Scientific and Technical Information 5 p (SEE N94-37333 12-82) Feb. 1994

(AGARD-CP-544) Copyright Avail: CASI HC A01/MF A02

This paper introduces the present scenario of networking the different systems of exchanging information person to person, the way to access the information and to know where the information is. A summary of the more utilized applications is made, some of them have appeared in the last years as the result of a normal evolution: bulletin boards, Gopher, WAIS, World-Wide Web, e-mail, conferencing, directory service, etc. All these applications represent an added value to networking allowing the user (scientist, engineer, librarian, etc.) to communicate with others on their same area of interest. Additionally the user can obtain information about how to connect to servers and get items, programs, data, etc., and to follow conferences or make questions in a forum. As an example of an important application of distributed directory the Paradise project is discussed, it yields some tools in order to look for information on institutions, people and other objects. Taking all these considerations into account, it is intended to make an analysis about the current use of these tools by engineers and scientists. The role that the libraries and information centers should play in this context is also discussed. Author (revised)

N94-37344# CAE Electronics Ltd., Saint Laurent (Quebec).
TRAINING AND OPERATIONS SUPPORT SYSTEM (TOPS)
GUY LANGLOIS and IAN GORDON *In* AGARD, International High Speed Networks for Scientific and Technical Information 3 p (SEE N94-37333 12-82) Feb. 1994
(AGARD-CP-544) Copyright Avail: CASI HC A01/MF A02

This paper describes a potential training and operations support system and discusses the enabling technologies that make it possible - high speed global networks, powerful computers, and an object oriented data base management system (OODBMS). It illustrates a real world example of the system using a scenario involving an aircraft maintenance technician. Author

N94-37345# WAIS, Inc., Menlo Park, CA.
WIDE AREA INFORMATION SERVERS: AN EXECUTIVE INFORMATION SYSTEM FOR UNSTRUCTURED FILES
BREWSTER KAHLE and HARRY MORRIS *In* AGARD, International High Speed Networks for Scientific and Technical Information 9 p (SEE N94-37333 12-82) Feb. 1994
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In this paper we present a corporation information system for untrained users to search gigabytes of unformatted data using quasi-natural language and relevance feedback queries. The data can reside on distributed servers anywhere on a wide area network giving the users access to personal, corporate, and published information from a single interface. Effective queries can be turned into profiles, allowing the system to automatically alert the user when new data is available. The system was tested by twenty executive users located in 6 cities. Our primary goal in building the system was to determine if the technology and infrastructure existed to make end-user searching of unstructered information profitable. We found that effective search and user interface technologies for end-users are available, but network technologies are still a limiting cost factor. As a result of the experiment we are continuing the development of the system. This paper describes the overall system architecture, the implemented subset, and the lessons learned. Author

N94-37346# France Telecom North America, New York, NY.
INFORMATION RETRIEVAL SERVICES ON WIDE AREA NETWORKS: A VISION OF THE FUTURE
J. LEMEZEC *In* AGARD, International High Speed Networks for Scientific and Technical Information 7 p (SEE N94-37333 12-82) Feb. 1994
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This paper refers to some existing systems and to R&D work, especially in France Telecom, in order to help define a vision of future systems and services that store and retrieve information on wide area networks. Special reference is made to the Minitel network, a videotex network involving 6 million terminals and 20,000 services; JPEG 'Minitel Photo' and the first Fast Speed Teletel services were developed in 1992. Other services prepared for short-term experimentation, include multimedia videotex on ISDN. Two main contributions to a future broadband multimedia network are then discussed: standardization of multimedia and the deployment of ATM (Asynchronous Transfer Mode). Finally, a vision of a multi-purpose worldwide network of networks is proposed and the challenges posed by its construction are presented.
Author (revised)

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14. Abstract

This volume provides abstracts and indexes for AGARD unclassified publications published during the period 1992-1994. Full bibliographical citations and abstracts for all the documents in this publication are given in the abstract section, which is organized in the major subject divisions and specific categories used by NASA in abstract journals and bibliographies. The major subject divisions are listed, together with a note for each that defines its scope and provides any cross-references. Category breaks in the abstract section are identified by category number and title, and a scope note. Within each category, the abstracts are arranged by series and year.

Six indexes — Subject (based on *NASA Thesaurus nomenclature*), Personal Author, Corporate Source, Panel, Report/Accession Number, and Accession Number — are included. Sample entries are shown on the first page of each index.

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